Carnegie Institution

OF

Washington

YEAR BOOK

No. 5

1906

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CARNEGIE INSTITUTION

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PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.
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PRESS OF JUDD & DETWEILER, INC.
WASHINGTON, D. C.

OFFICERS FOR THE YEAR 1907

President of the Institution

ROBERT S. WOODWARD

Trustees

Executive Committee

Finance Committee

* Ex-officio member.

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LIST OF ILLUSTRATIONS.

ARTICLES OF INCORPORATION.

The Carnegie Institution was originally organized under the law governing the organization of corporations in the District of Columbia. Owing to certain limitations in the law, the Trustees deemed it desirable to obtain articles of incorporation from the Congress. Accordingly, articles of incorporation were prepared, submitted to the Congress, amended by the Congress, and enacted into statute by the Congress and the signature of the President.

Organization under the new articles of incorporation was effected on May 18, 1904. Resolutions were passed electing the same Executive Committee and officers as those of the Carnegie Institution organized in 1902 and continuing all instructions and authorizations given to the Executive Committee by the old organization.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the Institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth, and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time

to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause

existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. No person shall be elected, however, who shall not have been nominated at a preceding annual or special meeting, except by the unanimous consent of the members present at a meeting.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the second Tuesday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized. He shall have custody of the seal of the corporation and shall affix the same whenever authorized to do so by the Board of Trustees or by the Executive Committee or the Finance Committee.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President, who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of all property of the Institution whose custody is not otherwise provided for. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing committees, viz, an Executive Committee and a Finance Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio*, and,

in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures, and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have general charge of the investments and funds of the corporation, and shall care for and dispose of the same subject to the directions of the Board and of the Executive Committee. It shall consider and recommend to the Board of Trustees such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting.

8. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Chairman of the Board, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property shall be deposited in such safe deposit or other corporation and under such safeguards as the Trustees and Executive Committee shall designate; and the moneys of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

Fourth Meeting of the Board of Trustees

DECEMBER 11, 1906

MINUTES OF THE FOURTH MEETING OF THE BOARD OF TRUSTEES

[Abstract.]

The meeting was held in Washington, at the New Willard Hotel, on Tuesday, December 11, 1906, at 10 o'clock a. m.

In the absence of the Chairman, the Vice-Chairman, Hon. Elihu Root, presided.

The following Trustees responded to a roll-call by the Secretary: John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Daniel C. Gilman, Charles L. Hutchinson, Seth Low, S. Weir Mitchell, Elihu Root, Charles D. Walcott, Andrew D. White, Carroll D. Wright, and President Woodward.

Mr. Andrew Carnegie, the founder of the Institution, was also present.

The following Trustees were absent: John S. Billings, Lyman J. Gage, Henry L. Higginson, E. A. Hitchcock, William Wirt Howe, William Lindsay, Wayne MacVeagh, D. O. Mills, William W. Morrow, and John C. Spooner.

The minutes of the third meeting of the Board were presented and were approved as printed in abstract.

The Reports of the President, of the Executive Committee, of the heads of departments, and grantees of the Institution were received and considered.

The death of Professor Samuel Pierpont Langley, Trustee, was announced.

The resignations of Mr. William Wirt Howe and Mr. Wayne MacVeagh were presented and accepted.

Hon. William H. Taft, Dr. Henry S. Pritchett, and Dr. William H. Welch were elected Trustees to fill three of the five vacancies in the Board.

Messrs. Gilman, Mitchell, and Wright were elected members of the Executive Committee to succeed themselves for a term of three years.

Messrs. Mills, Higginson, and Low were elected members of the Finance Committee for three years.

Balloting for officers of the Board for the three years ensuing resulted in the reelection of Mr. Billings as Chairman, Mr. Root as Vice-Chairman, and Mr. Dodge as Secretary.

The recommendations of the Executive Committee relative to plans for a proposed administration building were accepted and approved.

The gift of Mr. John D. Hooker, of Los Angeles, California, of a sum sufficient to purchase and figure a mirror 100 inches in diameter for the Solar Observatory was accepted.

The question of publishing an edition of classic works on international law was referred to the Executive Committee with power.

After discussion, the following general appropriations were made:

Publication fund, to be continuously available	$70,000
Administration	50,000
Grants for departments and large projects	443,200
Grants for previously implied investigations, new minor investigations, and research associates and assistants	98,100
Total	$661,300

At 2 p. m. the Board adjourned.

Memorial.

The Trustees of the Carnegie Institution of Washington direct that the following Minute be made in the permanent records of the Institution:

Samuel Pierpont Langley, Secretary of the Smithsonian Institution since 1887, and Trustee of the Carnegie Institution of Washington since its foundation, died at Aiken, South Carolina, February 27, 1906.

Distinguished for his brilliant investigations in astronomy, astrophysics, and aerodynamics especially, and keenly interested in all enterprises for human advancement, he watched the development of this Institution with an enthusiasm tempered by sound judgment and sane expectations.

He was one of the first to suggest a combined observatory and laboratory for the study of solar physics, and his advice and co-operation have been of signal service in the inauguration of the Solar Observatory on Mount Wilson.

Manifesting in an unusual degree the zeal, the industry, and the comprehension essential to effective achievement in scientific pursuits, his life and work present a conspicuous example to his colleagues and successors who are charged with the duty of promoting original research.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

REPORT OF THE PRESIDENT OF THE INSTITUTION.

Introductory Statements.

In compliance with the provisions of Article IV of the By-Laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1906, along with recommendations of appropriations for the following year, and with sundry suggestions concerning pending and prospective questions presented by the development of the Institution.

The year just ended has been one of great activity in all of the principal branches of work carried on under the auspices of the Institution. This is especially the case with all of the larger departments of work, which, in spite of the fact that they are only fairly started, are already producing noteworthy results.

The mode of administration of the work of the Institution, explained in my report of the preceding year, has been followed essentially during the past year, and hence needs no additional explanation here.

The research as distinguished from the administrational activities of the Institution may be classified roughly under the four following heads, which are the same as those used in my preceding report, namely:

1. Large projects carried on under the direct auspices of the Institution by departments having corps of investigators.
2. Minor projects carried on by individuals temporarily affiliated with the Institution.
3. Work of research associates and assistants.
4. Work of publication.

This classification may serve to indicate the lines of division for the details of subsequent parts of this report.

Financial Statement for the Fiscal Year 1905-1906.

The following table shows the unallotted balances brought forward from appropriations of previous years; the amounts appropriated for the year by the Board of Trustees at their meeting of December 12, 1905; the revertments during the year; the totals available for expenditure during the year; and the unallotted balances at the end of the year for large grants, minor grants, research associates, publication, and administration, respectively. To con-

nect the figures of this table with those of the corresponding table given in my preceding report, it should be observed that of the unallotted balance of $114,894.75 at the end of the previous year (October 31, 1905) an amount of $102,176.79 was reverted to the unappropriated fund by action of the Executive Committee November 6, 1905.

	Unallotted Oct. 31, 1905.	Appropriation, Dec. 12, 1905.	Revertments Oct. 31, 1905, to Oct. 31, 1906.	Total.	Allotments.	Balances unallotted Oct. 31, 1906.
Large grants	....	$552,600	....	$552,600.00	$459,450.00	$93,150.00
Minor grants	$1,750.00	108,000	$10,853.05	120,603.05	95,650.00	24,953.05
Research associates and assistants	....	26,000	....	26,000.00	5,600.00	20,400.00
Publication	565.00	50,000	5,248.12	55,813.12	47,297.59	8,515.53
Administration	10,402.96	50,000	.44	60,403.40	42,534.90	17,868.50
	12,717.96	786,600	16,101.61	815,419.57	650,532.49	164,887.08

The following list shows the departments of investigations to which the arger grants were made by the Trustees and the amounts thus far allotted during the year to those grants by the Executive Committee:

Department of Experimental Evolution	$21,000
Department of Marine Biology	15,000
Department of Botanical Research	33,000
Horticultural Work (L. Burbank)	10,000
Department of Economics and Sociology	30,000
Department of Terrestrial Magnetism	54,000
Department of Historical Research	14,450
Solar Observatory	150,000
Geophysical Research:	
A. L. Day	17,500
F. D. Adams	1,500
Bibliography (G. F. Becker *et al.*)	1,000
Geophysical Laboratory	85,500
Southern Observatory	10,000
Nutrition:	
F. G. Benedict	10,000
R. H. Chittenden	1,500
T. B. Osborne	5,000
	459,450

The fields of investigation to which the minor grants were assigned, the names of the grantees, and the amounts of the grants are shown in the following list:

Anthropology:	
Dorsey, G. A	$3,000
Archeology:	
American School of Classical Studies:	
Athens	2,500
Rome	2,600
Brigham, W. T	2,500
Müller, W. Max	2,000
Ward, W. H	250
Astronomy:	
Boss, L	8,000
Campbell, W. W	4,000
Davis, H. S	1,500
Newcomb, S	5,000
Bibliography:	
Index Medicus	10,000
Eames, W	3,600
Botany:	
Cowles, H. C	300
Account of the work of Mr. Burbank	3,500
Chemistry:	
Acree, S. F	300
Jones, H. C	1,000
Bancroft, W. D	1,000
Baxter, G. P	1,000
Morse, H. N	1,500
Noyes, A. A	2,000
Richards, T. W	2,500
Geology:	
California Earthquake Commission	$5,000
Chamberlin, T. C	6,000
Willis, B	5,775
History:	
Haskins, C. H	1,000
Literature:	
Sommer, H. O	2,000
Mathematics:	
Lehmer, D. N	400
Meteorology:	
Bjerknes and Sandström	1,200
Paleontology:	
Wieland, G. R	375
Philology and Linguistics:	
Flügel, E	7,500
Scripture, E. W	1,800
Physics:	
Burgess, C. F	2,500
Franklin and Freudenberger	250
Physiology:	
Chittenden, Russell H	1,000
Zoology:	
Castle and Mark	500
Naples Zoological Station	1,000
Mark, E. L	300
Pearl, R	500
Wilson, E. B	500
	95,650

The following table shows the fields of investigation, the names of research associates and assistants, and the amounts of their grants:

Field of investigation.	Names of research associates and assistants.	Amount of grants.
Anthropology	Jones, W.	$1,000
Economics	Rowe, L. S.	300
History	Ferguson, W. S.	1,200
Psychology	Farrar, C. B.	1,000
Zoology	Johnson, R. H.	1,100
	Blakeslee, A. F.	1,000
Total		5,600

The following grants for publication were authorized during the year:

Adams and Coker	$131.89	Newcomb, Simon	$1,500.00
Banta, A. M	500.00	Noyes, A. A	1,600.00
Barus, Carl	1,200.00	Pearl, Raymond	550.00
Benedict, F. G	130.91	Pearl and Clawson	300.00
Burnham, S. W	3,713.44	Perez, L. M	700.00
Case, E. C	2,200.00	Pumpelly, Raphael	6,000.00
Castle, W. E	200.00	Richards and Forbes	375.00
Coblentz, W. W	700.00	Sommer, H. O	6,000.00
Davenport, C. B	1,048.09	Stevens, N. M	200.00
Dean, Bashford	299.68	Stevens, N. M	300.00
Dorsey, George A	1,500.00	Walcott, C. D	165.00
Farlow, W. G	400.00	Washington, H. S	1,000.00
Goss, W. F. M	1,400.00	Willis, B	6,400.00
Jones, H. C	2,400.00	Wieland, G. R	1,258.58
Livingston, B. E	350.00	Wood and Uhler	1,200.00
Morse, A. P	350.00	Reprint, No. 22	225.00
Müller, W. Max	3,000.00		
			47,297.59

The sources and the amounts of the revertments during the year are as follows:

REVERTMENTS FROM NOVEMBER 1, 1905, TO OCTOBER 31, 1906.

Minor grants:		
Herman S. Davis, grants Nos. 232 and 320	$2,625.00	
V. M. Spalding, grant No. 287	600.00	
O. F. Cook, grant No. 254	2,000.00	
G. K. Gilbert, grant No. 126	919.31	
Arthur Gamgee, grant No. 62	3,040.00	
A. C. McLaughlin, grant No. 186	175.00	
F. J. Bliss, grant No. 99	1,250.00	
W. F. M. Goss, grant No. 114	198.87	
Bailey Willis, grant No. 116	44.87	
		$10,853.05
Publication:		
Historical research	1.48	
George A. Dorsey	80.24	
Bailey Willis, grant No. 261	20.00	
Carl Barus	116.33	
M. W. Whitney	38.55	
N. M. Stevens	32.90	
Reprint, Publication No. 22	10.78	
W. E. Castle	42.60	
Erwin F. Smith	4,314.24	
Bailey Willis, grant No. 280	76.85	
B. E. Livingston	16.78	
W. Max Müller	497.37	
		5,248.12
Administration		.44
		16,101.61

RÉSUMÉ OF WORK OF THE YEAR.

Range of Work of the Institution.

In my preceding report attention was called to the desirability of conferring personally with all investigators at work under the auspices of the Institution and inspecting laboratories, observatories, and other establishments where work is under way. Much progress in this regard has been made during the year, altho much remains to be done. In the meantime the work of the Institution has undergone considerable expansion; so that it may be stated that we are now working in cooperation in one way or another with about one hundred different institutions and establishments thru about four hundred individuals. The range and ramifications of the work are thus very extensive, making it difficult of comprehensive and summary explanation. Attention is therefore invited to the detailed reports of the heads of departments of investigation and to the reports of individual investigators to be found on pages 53–251.

The Larger Projects.

In conformity with the authorization of the Board of Trustees voted at their meeting of December 12, 1905, a new department of work has been added to the ten larger projects enumerated in my preceding report. This new department is occupied with measurements of the positions and the motions of the so-called fixed stars, and it contemplates, as one of the essential parts of its program, the temporary establishment of an observatory in the southern hemisphere. Since the work of this department is chiefly devoted to meridian measurements and their applications, it may be conveniently designated as the Department of Meridian Astrometry. This department has been placed in charge of Prof. Lewis Boss, of the Dudley Observatory.

In conformity with a like authorization of the Board of Trustees, the work of the Desert Botanical Laboratory, which was previously conducted by a non-resident advisory committee, has been enlarged and placed under the charge of Dr. Daniel T. MacDougal as resident director. Since the scope of the work is chiefly botanical in this department, it has been conveniently designated as the Department of Botanical Research.

Applying departmental designations so far as practicable, the larger projects now under way are enumerated alphabetically in the following list, which gives also the names of the directors of the departments, or the principal investigators, as the case may be, conducting the researches:

Botanical Research: D. T. MacDougal, director.
Economics and Sociology: Carroll D. Wright, director.
Experimental Evolution: Charles B. Davenport, director.
Historical Research: J. F. Jameson, director.
Horticulture: Luther Burbank.

Marine Biology : A. G. Mayer, director.
Meridian Astrometry : Lewis Boss, director.
Nutrition : F. G. Benedict, R. H. Chittenden, L. B. Mendel, and T. B. Osborne.
Solar Physics : George E. Hale, director.
Terrestrial Magnetism : L. A. Bauer, director.
Work in Geophysics : F. D. Adams, G. F. Becker, A. L. Day.

Referring to the individual reports of the directors and investigators just named for matters of detail, the following summary remarks may serve to indicate in a general way the present status and the prospective outcome of departmental investigations.

Department of Botanical Research.

Immediately after the authorization of this department by the Trustees at their meeting of December 12, 1905, the nomination of Dr. D. T. MacDougal for the position of Director was approved by the Executive Committee. Dr. MacDougal accepted the position and proceeded at once to take up the work already well started at the Desert Laboratory at Tucson, Arizona. During the year he has enlarged the laboratory by the addition of a wing, affording much-needed room ; secured a good water supply for laboratory use ; fenced in the reservation of 840 acres set apart by the Territory of Arizona for the laboratory, and provided several stations on near-by mountains for the study of conditions of plant life at alpine heights. To this equipment on the material side he has added an adequate staff of three resident investigators and an efficient engineer.

The provision thus made gives the department unrivaled opportunities for the pursuit of research with respect to the flora of arid regions in particular, and this should contribute in an important degree to the progress of botanical research in general. Attention is called to some noteworthy papers, cited in the bibliography on pages 45–52, which have appeared during the year from members of the departmental staff.

The President desires to express his appreciation of the hearty spirit of cooperation shown by Director MacDougal in assenting to the temporary transfer of his engineer, Mr. Godfrey Sykes, to the staff of the Solar Observatory on Mount Wilson. In an emergency case of road-building on this mountain the services of Mr. Sykes have been specially opportune and efficient.

Department of Economics and Sociology.

Under the energetic administration of Dr. Wright the large undertaking of the Department of Economics and Sociology has made steady progress during the year. About 130 collaborators are engaged in the work, and many separate contributions are now nearly ready for publication. Provision for several volumes of reports and statistics prepared by the department has already been considered by the Executive Committee. A noteworthy contribution well under way is a bibliographic index to the public documents of

the States of the United States. The data for several States are now ready for publication, and the work of printing will doubtless be started during the coming year.

Department of Experimental Evolution.

One of the most promising as well as novel and interesting departments of work started by the Institution is that devoted to experimental evolution at Cold Spring Harbor, Long Island, New York, under the direction of Prof. Charles B. Davenport. In this department an attempt is being made to determine by direct observation and experiment the characteristic relations, or laws, manifested by the complicated process of evolution in plants and animals. Thus the phenomena of heredity, hybridization, mutation, etc., are here studied by substantially the same methods as those applied by the astronomer to the stars or by the chemist to inorganic matter. And just as these methods have yielded an abundant harvest of valuable results in the latter sciences, so may we confidently anticipate at least equally valuable results from the application of like methods to the problems of evolution. The intrinsic difficulties of these problems are very great, however, and they demand, therefore, an ample allowance of time as well as a peculiar degree of patience for their solution. For the work of this department especially, and for nearly all of the departmental work of the Institution in fact, a decade is the smallest convenient time unit for measuring the progress of the more important investigations now under way.

As may be seen from the report of the Director (pages 92–104) and from the bibliography (pages 45–52) several publications have issued from the department during the year, the most noteworthy of which is a contribution entitled "Inheritance in Poultry," by Professor Davenport.

Work in Geophysics.

Geophysical investigations have been carried on independently during the year along three distinct lines by three investigators, namely, Prof. F. D. Adams, of McGill University, Montreal, and by Dr. George F. Becker and Dr. Arthur L. Day, of the U. S. Geological Survey. As explained at length in my report of the preceding year, the novel experimental work under the direction of Dr. Day requires unusual laboratory facilities, especially in the way of high-temperature and high-pressure equipment and ample space therefor. To meet this requirement, the Trustees at their last meeting, in response to a recommendation of the Executive Committee, voted an appropriation of $150,000 for the purchase of a site and for the construction and equipment of a laboratory adequate to this work. Accordingly a site of five acres of land, on an isolated hill in the subdivision known as Azadia, in the District of Columbia, was purchased. Title was acquired to this site on March 17, 1906. Plans for the proposed laboratory were prepared by Messrs. Wood, Donn and Deming, architects, of Washington, D. C., and the contract for the construction was let to Richardson and Burgess, Inc., of Washington, D. C., on July 6, 1906.

Work of construction is now moving rapidly forward, and it is expected that the laboratory will be ready for occupancy not later than July 1, 1907.

The researches of all three investigators in this field have been prosecuted vigorously during the year, and many results have been announced, as shown by the list of publications issued (page 31) and in the bibliography (pages 45–52). Amongst these important results it may suffice here to instance two only, namely, the volume by Professor Adams and his associate, Professor Coker, on the elastic properties of some of the principal rocks, of interest and value alike to the geologist and the engineer; and the process developed by Dr. Day for the production of the remarkable substance known as quartz glass, which promises to be of great practical value by reason of its high melting point and its low rate of expansion under temperature changes.

Department of Historical Research.

Attention is specially invited to the full text of the first report of Prof. J. F. Jameson, who succeeded Prof. Andrew C. McLaughlin as Director of the Department of Historical Research in October, 1905. In an unusual degree the field of this department presents a somewhat bewildering array of opportunities for fruitful research, whether carried on independently or by cooperation with other agencies. There is thus room for the play of a great variety of opinions, many of which must be conflicting, with respect to the proper functions of such a department. Under these circumstances it is no easy task to fix on a program which may command a consensus of approval from professional historians and come within the limits of administrative necessities. In his report for the year the Director outlines a program which appears to meet these requirements and to demand only time, patience, and industry, along with adequate support, for its successful execution.

Early in the year Professor Jameson visited several European countries, inspecting similar departments of work there and searching especially for the sources of American historical documents in foreign archives.

A bibliography of works on American History and a reprint of Professor McLaughlin's Report on the Diplomatic Archives of the Department of State, 1789–1840, have been issued by the department during the year. Several reports on American historical materials in the archives of England, Spain, Cuba, and the United States have been brought also to a forward state of preparation for publication.

Horticultural Work of Mr. Luther Burbank.

Mr. Burbank reports that the year just passed has proved very successful for the extensive experiments and investigations in plant, fruit, and flower development carried on by him thru aid granted by the Institution. By great good fortune the earthquake which proved so destructive to the city of Santa Rosa in which he lives and to the surrounding country, did very little damage to his property. In one respect, doubtless, the earthquake was advantageous

to him and to his work, namely, in preventing visitors from encroaching too freely on his time and attention.

Thru the agency of a committee, consisting of the President, as chairman, and of Messrs. Davenport, MacDougal, and Mayer, heads of the departments of biological research, the task of preparing a scientific account of the ways, means, and methods employed by Mr. Burbank in his unrivaled work has been undertaken during the year. In May last all members of this committee except Dr. Mayer visited Santa Rosa and conferred with Mr. Burbank in order to develop a program for this undertaking. In accordance with this program, the details of which need not be stated here, Dr. George H. Shull, of the staff of the Department of Experimental Evolution, spent a portion of the summer in work at Santa Rosa, and he has recently returned thither to resume his labors. It is contemplated to have Dr. Shull spend parts of two or three years at work with Mr. Burbank, and to call to our aid also the services of other specialists of the departments of biological research.

Altho space forbids a further account of this work here, the President desires to record his warm esteem of the scientific spirit of cooperation shown in this enterprise by Mr. Burbank, by the members of the committee, by Dr. Shull, and by numerous colleagues whose counsel has been sought. By means of the cooperation thus secured it is confidently believed that the diverse scientific and economic ends in view may be achieved in ways which will commend themselves alike to the Institution and to the general public.

Department of Marine Biology.

The location of the laboratory of the Department of Marine Biology at Dry Tortugas, Florida, has required a development along somewhat different lines from those followed by other departments. Altho this location is uniquely favorable in respect to abundance of marine fauna available, it is so isolated and so subject to tropical storms that the laboratory may not be safely kept open for investigation thruout the year. Thus far, therefore, the Director, Dr. Mayer, has not sought to attach to his department a permanent scientific staff. Instead of doing so he has invited, during each of the past two summer seasons, a number of trained investigators to become guests of and to pursue investigations at the laboratory. For this purpose the Executive Committee has allotted to the department a sufficient sum to cover the costs of the traveling expenses and the subsistence, while at the laboratory, of these guests. Under the administration of Dr. Mayer this tentative plan has worked so promisingly that it appears to me well worthy of consideration with a view to its application to some other departments. By a proper selection of associate investigators and by limiting eligibility to men and women of proved capacity for research, an extension of this plan to other departments may be expected not only to stimulate fruitful activity amongst

competent investigators but also to mitigate the difficulties which beset the administration of minor grants to miscellaneous applicants. The attention of the Trustees is therefore especially invited to the aspects of this subject explained in reference to his department by Dr. Mayer in his reports of the past and preceding years. That the work of the department will prove adequately productive in spite of the climatic obstacles in its way is sufficiently indicated by the reports cited and by the accompanying bibliographic lists.

Nutrition.

The same investigators engaged in research along three distinct lines in this field under the auspices of the Institution during the preceding year have continued their work during the past year. Thus Prof. F. G. Benedict has extended and perfected his experiments with the respiration calorimeter at Wesleyan University; Professors R. H. Chittenden and L. B. Mendel have carried forward their fundamental investigations in physiological chemistry at Yale University, while Dr. T. B. Osborne, of the Connecticut Agricultural Experiment Station at New Haven, has made excellent progress in his capital researches on the chemistry of the vegetable proteid foodstuffs.

All three of these lines of research are of great practical and theoretical importance, whether considered independently or collectively. They are closely related, however, and when considered as parts of a whole they give promise not only of extensive additions to our knowledge of the physics and chemistry of normal nutrition, but also of extensive additions to our knowledge of the conditions of and the remedies for abnormal nutrition. All three lines of work appear to me, therefore, well worthy of continuous support for such periods of time as may be essential to secure the anticipated results.

The branch of this work carried on by Professor Benedict calls for a special equipment and for a laboratory of unusual character. It appears particularly desirable, also, to apply the calorimetric method to pathological as well as to normal subjects of investigation. Hence some additional recommendations in reference to this work will be submitted to the Trustees for consideration at their next meeting.

Department of Meridian Astrometry.

In accordance with a recommendation of the Executive Committee the Trustees voted at their meeting of December 12, 1905, an appropriation of $200,000, to be distributed over a decade, for the purpose of preparing a catalog giving precise positions of all stars from the brightest down to those of the seventh magnitude, inclusive. One of the essential features of this work is the establishment for a few years of a meridian observatory in the southern hemisphere in order to supplement by additional observations existing data for the positions of stars in that hemisphere. The execution of this enterprise has been intrusted to Prof. Lewis Boss, the director of the Dudley

Observatory of Albany, New York. An outline of the preliminary arrangements required for the work is given by Professor Boss in his report, on pages 204–211. Hence it may suffice here to state that all essential plans are perfected for a rapid and effective consummation of this arduous undertaking.

Department of Solar Physics.

The varied and extensive operations of this department, under the direction of Prof. George E. Hale, on Mount Wilson and at Pasadena, California, have made gratifying progress during the year. While the artificers have been busily engaged, at the Union Iron Works at San Francisco and at the shops of the department at Pasadena, in perfecting the mountings and equipment of the 60-inch reflecting telescope, the staff at the Solar Observatory on Mount Wilson has been equally active with the present limited equipment in the work of observation and in the more difficult work of interpreting the observed data.

The great telescope just mentioned is now being mounted in a testing laboratory at Pasadena, and its parts are expected to be ready for transportation to the summit of Mount Wilson early next spring. An indispensable adjunct to the observatory on Mount Wilson is a physical laboratory, which has been completed, equipped, and put in operation during the year. By means of this laboratory many of the phenomena observed in the sun may be reproduced artificially and studied thus deliberately and repeatedly.

As explained in detail by Professor Hale, in his report on pages 60–86, important results from the preliminary observations and studies at the observatory have been already attained. Additional results are also forthcoming, and there is no reason to doubt that these and other direct results which may be expected to accrue rapidly will more than justify the cost of this formidable enterprise.

The signal success achieved by Prof. G. W. Ritchey, of the observatory staff, in figuring and mounting reflecting telescopes has justly won the admiration of the astronomical world and led other establishments to seek his aid in telescopic construction. More gratifying still to him, to his colleagues, and to the Institution is the enlightened appreciation of his skill and the work of the Solar Observatory shown by Mr. John D. Hooker, a citizen of Los Angeles, California, who has offered to place at the disposal of the observatory a sum sufficient to purchase and to figure a mirror 100 inches in diameter for a reflecting telescope. This generous offer of Mr. Hooker has been recommended to the Trustees for acceptance by the Executive Committee. It is appropriate to state, also, in this connection, that the Solar Observatory is indebted to Mr. Hooker for a cottage on Mount Wilson, presented to the observatory before it became formally one of the permanent establishments of the Institution. This cottage is now known as "The Hooker Cottage," and is used chiefly for the accommodation of transient guests.

An auxiliary matter of great moment to the Solar Observatory is that of a roadway from the foot to the summit of Mount Wilson. By the terms of the ninety-nine year lease of the observatory site secured by the Institution the privilege was granted not only to use but to repair and improve an existing road or trail controlled by the lessors. The approaching completion of the 60-inch telescope referred to above made it essential to decide early in the year how the parts of this telescope could be most advantageously transported to the observatory site. Accordingly, at the request of Professor Hale, the President visited Pasadena during May and June last, and, after several conferences on the matter and after a careful study of its various aspects, a decision was reached to undertake widening and improving the existing trail to the extent required for safe transport of apparatus, materials, etc., up and down the mountain. Since an estimate of $15,000 for this work in the budget of the department for the year had been approved by the Executive Committee, it was possible to start the work at once. Thru the courtesy of the Director of the Department of Botanical Research a member of his staff, Mr. Godfrey Sykes, was temporarily transferred to the staff of the observatory and placed in charge of this work. Under his direction the road is now well advanced and it is expected to be ready for use early next year.

Department of Terrestrial Magnetism.

The extensive field and office researches of this department have secured during the year large additions to magnetic data from widely separated parts of the earth. Land observations for magnetic elements have been made at numerous stations in the United States, Canada, the Pacific islands, and China, while the observing ship *Galilee* has been continued during the year in the magnetic survey of the Pacific Ocean started during the preceding year.

During her first voyage, beginning August 5, 1905, and ending December 9, 1905, this ship traversed circuits aggregating 11,000 nautical miles. During her second voyage, beginning March 2, 1906, and ending October 13, 1906, she traversed circuits aggregating 15,000 nautical miles. The success attending these expeditions has been highly satisfactory from the points of view jointly of quantity and quality of the observations obtained. From the extensive additions to existing knowledge of the magnetic elements of the Pacific thus gained it will soon be practicable to produce greatly improved magnetic charts for the benefit of the rapidly growing commerce of this ocean.

Only one serious mishap has occurred to the *Galilee* during her two voyages for the department. This took place on August 24, 1906, when she was blown ashore and sunk during a typhoon while at anchor in the harbor of Yokohama, Japan. Thanks to the prompt action of her owner, Mr. Matthew Turner, of San Francisco, she was speedily raised, repaired, and made ready to proceed by September 5, 1906.

Office computations of the department have proceeded simultaneously with the progress of field work, and many results will be ready soon for publication. Amongst the latter attention may be called to a magnetic chart of the United States which Director Bauer is now able to found on trustworthy data from about three thousand well-distributed stations. Most of these data, it should be stated, have been collected by Dr. Bauer and his colleagues of the U. S. Coast and Geodetic Survey, but they have been supplemented recently to a noteworthy degree by work in Canada especially under the auspices of the Institution.

One of the interesting incidental contributions from the work of the department during the year, illustrating the close interrelations of the geophysical sciences, is a complete set of records of the earth tremors generated by the San Francisco earthquake of April 18, 1906, obtained from magnetographs and seismographs at the widely separated magnetic stations of Cheltenham, Maryland; Baldwin, Kansas; Sitka, Alaska, and Honolulu, Hawaiian Islands.

On the 1st of July, 1906, Director Bauer severed his connection with the U. S. Coast and Geodetic Survey, of whose magnetic work he has had charge for some years, in order that he might devote his entire time to the larger field of magnetic work undertaken by his department.

The great practical and theoretical importance of the work carried on by this department not only commends its maintenance at the present rate of annual appropriations, but calls also for some additional support when funds are available. Altho the yacht *Galilee* has proved quite satisfactory, she could be replaced very advantageously by a ship having less iron in the make-up and an auxiliary screw propulsion, which latter would be of great aid in "swinging ship" for the elimination of the effects of the vessel's own magnetism. It may become essential also to establish for a series of years, in some hitherto unoccupied parts of the world, a few stations where continuous records may be observed. The need is already felt likewise for a specially equipped laboratory, located in a position isolated from the disturbing influence of electric circuits, where instruments may be tested and standardized.

Minor Projects.

Altho a smaller number of new grants in aid of projects carried on by individuals has been made during the past year than during preceding years in the history of the Institution, many such projects were under way. By reference to lists on pages 19 and 20 it will be seen that 45 such grants were subject to payments during the year. A considerable number of researches under former grants were also under way, and some of these have resulted in publications under the auspices of the Institution or in current journals. A bibliography of the latter, obtained by aid of the authors themselves, is given on pages 45–52. It

should be stated also that several grantees engaged in individual researches have joined the staffs of the departments to which their work was closely related.

The extent and variety of these researches forbid anything like an adequate account of them here. Most of those cited in my preceding report as specially worthy of mention were continued during the year, and nearly all of these have produced publications already issued or in press.

Three new projects under this head may be alluded to, namely:

1. The preparation for publication of a critical edition of the Vulgate Version of the Arthurian Romances, by Dr. H. Oskar Sommer, of London, England. The manuscript of the first two parts of this work has already been received from Dr. Sommer, and preparations are now being made for printing them in appropriate form.

2. The preparation of an advanced treatise on meteorology, together with suitable numerical tables to facilitate practical applications, by Prof. V. Bjerknes and Mr. J. W. Sandström, of the University of Stockholm. The first part of this work is expected to be ready for publication before the end of this calendar year.

3. Soon after the occurrence of the San Francisco earthquake of April 18, 1906, a commission, known as the California Earthquake Commission, was formed to examine and report upon the remarkable and wide-spread effects of the shock. This commission consists of Prof. Andrew C. Lawson, chairman; Prof. J. C. Branner, Prof. Charles Burckhalter, Prof. W. W. Campbell, Prof. George Davidson, Dr. G. K. Gilbert, Prof. A. O. Leuschner, and Prof. H. F. Reid. In response to an application from this commission a grant of $5,000 was made to aid in the collection of data on the causes and effects of the earthquake. Probably few, if any, earthquakes have been carefully studied by such competent observers as the members of this commission, most of whom happened to be, fortunately, where they were awakened by the first marked tremors of the shock.

With regard to minor projects in general and with regard to the relative merits of major and minor projects, some extended observations will be found in a subsequent part of this report. It may be remarked here, however, that the experience of the Institution thus far with minor grants appears to me to have been on the whole quite unfavorable to them, altho the knowledge thus gained of this commonly approved system of awards is doubtless worth all it has cost. Briefly stated, this experience seems to show that the probability of getting anything more than an educational return from miscellaneous applicants who come highly recommended to the Institution is not more than one-half. On the other hand, this experience seems to show very clearly that if awards were limited more closely to applicants of proved capacity for and of proved opportunity for research the probability

of adequate returns would rise to practical certainty. In almost every case, in fact, in which aid has been given to investigators of such proved capacity and opportunity good returns have been realized. Thus are we confronted by the stubborn realities that there is no royal road to learning, and that of the many who feel drawn toward the high calling of investigation few may be chosen with the expectation that they will prove fertile in resources and fruitful in results.

This field of work is one of the most promising of those entered by the Institution. It is a field from which good results may be gleaned readily and made available speedily to the world at large. Thus far 57 volumes have been issued by the Institution and 31 volumes are now in press.

Publications and their Distribution.

The following is a list of the 19 volumes issued during the past fiscal year:

Year Book No. 4, 1905. Octavo, VIII + 303 pages, 7 plates.
Index Medicus, vol. 3. Octavo, 1449 pages.
No. 9. The Collected Mathematical Works of G. W. Hill. Quarto, 4 vols. Vol. 2, VII + 339 pages; vol. 3, 577 pages.
No. 22. Report on the Diplomatic Archives of the Department of State, 1789–1840. By A. C. McLaughlin. Octavo, 73 pages. Revised edition.
No. 34. American Fossil Cycads. By G. R. Wieland. Quarto, VII + 296 pages, 51 plates, 141 figures.
No. 36. Studies in Spermatogenesis, part II. By N. M. Stevens. Octavo, 44 pages, 8 plates.
No. 38. Writings on American History, 1903. Prepared under direction of A. C. McLaughlin. Octavo, 172 pages.
No. 40. The Nucleation of the Uncontaminated Atmosphere. By Carl Barus. Octavo, XII + 152 pages, 104 figures.
No. 41. Traditions of the Caddo. By G. A. Dorsey. Octavo, 136 pages.
No. 42. A Respiration Calorimeter with Appliances for the Direct Determination of Oxygen. By W. O. Atwater and F. G. Benedict. Octavo, 193 pages, 49 figures.
No. 45. Catalogue of Stars within two degrees of the North Pole, deduced from Photographic Measures. By Caroline E. Furness. Octavo, 85 pages.
No. 46. An Investigation into the Elastic Constants of Rocks, more especially with reference to Cubic Compressibility. By F. D. Adams and E. G. Coker. Octavo, 69 pages, 26 figures, 16 plates.
No. 49. Heredity of Hair-length in Guinea-pigs, and its Bearing on the Theory of Pure Gametes. By W. E. Castle and Alexander Forbes. (Paper No. 5, Station for Experimental Evolution.) The Origin of a Polydactylous Race of Guinea-pigs. (Paper No. 6, Station for Experimental Evolution.) By W. E. Castle. Octavo, 29 pages.
No. 50. The Relation of Desert Plants to Soil Moisture and to Evaporation. By Burton E. Livingston. Octavo, 78 pages, 16 text cuts.
No. 51. Studies on the Germ Cells of Aphids. By N. M. Stevens. Octavo, 28 pages, 4 plates.
No. 52. Inheritance in Poultry. (Paper No. 7, Station for Experimental Evolution.) By C. B. Davenport. Octavo, 136 pages, 17 plates.
No. 53. Egyptological Researches. By W. Max Müller. Quarto, 62 pages, 106 plates.
No. 57. The Roman Comagmatic Region. By H. S. Washington. Octavo, 199 pages.

These publications aggregate 3,166 octavo pages and 1,288 quarto pages, making a total of 4,454 pages.

The total amount of funds spent by the Institution for publications up to date is $77,123.53. The total amount spent for publications during the past fiscal year is $42,431.19.

It is an obvious requirement in this work to maintain a high standard of excellence, especially in point of the subject-matter published, altho it is equally obvious that the attainment of this end is no easy task. Moreover, a limited income is incompatible with unlimited publications, however abundant worthy contributions may appear to be. Hence follows the necessity of declining much of the large amount of material offered for publication. Plainly, also, the Institution may not undertake, in general, the publication of certain classes of works, like text-books, fiction, literary essays, doctorate dissertations, etc. Neither may the Institution appropriately provide funds for the publication of such works by commercial establishments. Nor is it practicable for the Institution to enter into partnership relations with authors and publishers, or with other institutions, under copyright privileges and restrictions.

The tentative rules for the distribution of publications approved by the Executive Committee January 9, 1905, and printed in my previous report, have worked fairly well thus far. A few important libraries for the gratuitous receipt of the publications of the Institution have been added during the year to the Omnia List, which now includes about 300 of the principal libraries of the world.

In response to a strong public demand for information concerning the publications of the Institution, an index of carefully selected addresses to which lists of these publications may be sent semi-annually, or quarterly, has been prepared during the year. This index now includes nearly 10,000 names of individuals and institutions and it will doubtless need enlargement in the near future. The first issue of the lists was made during the early part of October of this year.

The question is often asked, "Why does not the Institution publish larger editions of its works and distribute them more freely?" Probably the time has not arrived when a completely satisfactory answer to this question can be given. But in the absence of adequate precedent to guide us it appears to be the part of wisdom to proceed conservatively and let experience point the way. In the meantime it may be stated that nothing short of an edition of 5,000 copies will meet the demand for a gratuitous distribution, while there is thus far no evidence to indicate that our standard edition of 1,000 copies will not in general meet all legitimate demands. It should be stated also that there is an actual necessity for reserving a part of these publications for sale, since some institutions and more individuals decline to receive publications gratuitously.

Since the trend of development of the Institution still hinges to some extent on the relative merits of large projects carried on under the direct supervision of the Institution itself and of small projects committed to individuals whose affiliation with the Institution may be only temporary, a large amount of attention has been given to this question during the year; much more in fact than to any other. It is a matter of daily correspondence, of daily interviews, and of daily importunities. With a desire to see all sides of this question and to hear all arguments thereon, the President has solicited much of this correspondence and many of these interviews. He has received a wealth of highly esteemed advice and suggestion along with much more that must be characterized either as impracticable of application or as fraught with grave danger if applied.

Large versus Small Projects.

A considerable portion of this advice and suggestion would make instructive reading if printed, altho they are in large degree conflicting and need, obviously enough, here and there, correction for personal equation; but, aside from greater concentration on matters of detail, they do not differ essentially in the aggregate from the advice and suggestion given by members of the advisory committees whose reports are printed in the earlier Year Books of the Institution. Hence it does not seem worth while to add to the bulk of printed discussion along this line, even in the cases of correspondence whose authors would doubtless approve publication of their views. The President desires here, however, to express his warm appreciation of the counsel on this question given him confidentially by many colleagues in the academic and scientific world. Whether this counsel has been pro or con as regards his own views an effort has been made to weigh it fairly.

In the meantime there have been some opportunities for reflection on the various aspects of the question, while the Institution is accumulating experience which, tho not as yet conclusive in its bearings, furnishes important indications of the lines along which development may be expected to be effective or ineffective. It seems desirable, therefore, to state here some of the provisional conclusions to which observation, experience, and reflection have forced me, not without opposition, in some cases, to preconceived notions.

Categorically these conclusions are the following:

First, that the Institution may not advantageously enter the fields now occupied by colleges and universities. It should be no part of the function of the Institution to endow scholarships and fellowships for indigent students, nor to supply helpers, assistants, apparatus, libraries, museum collections, etc., for purely educational work, nor to supplement meager salaries of college and university professors whose work is primarily educational. This conclusion and the specifications enumerated seem so axiomatic that their statement would be quite superfluous here if the Institution were not daily importuned for aid in one or more of these and many similar ways.

Some eminent minds maintain, indeed, that since the object of the Institution is, in the last analysis at any rate, educational, these numerous ways of promoting education should not be overlooked, for the sphere of effective influence of the Institution, it is argued, may be thus widely extended. The experience of the Institution thus far, however, appears to be in direct opposition to this view. We are learning how the giving of aid by one institution to another, even indirectly, tends to sap the independence and to diminish the available income of both. Moreover, we encounter by this method the endless difficulties arising from diverse interests and divided responsibilities, along with the inevitable bitterness of disappointment from those who feel that the distribution of funds has not been equitable amongst the fields of research or amongst the institutions supplying the investigators.

Secondly, that the Institution may not advantageously seek to scatter its resources simultaneously over all available fields of research. It should rather choose a limited number of fields of activity at any epoch and concentrate its energies on these until they are brought to a satisfactory degree of completion. This conclusion seems likewise almost axiomatic, since it is determined essentially by a limited income. Many, if not a majority, however, of highly esteemed colleagues oppose this conclusion, and argue that a distribution of income in small grants to widely scattered investigators will be more productive in immediate results and of more ultimate benefit to society. But this argument does not appear to be supported by the experience of the Institution. It is impossible, of course, to draw precise inferences from this limited experience; but after a careful examination of the facts at hand I think it safe to state that no direct return may be anticipated from more than half of the small grants made up to the present time for minor researches and for research assistantships. Moreover, it appears to me that this is as high a percentage of efficiency as may be reasonably expected from miscellaneous applicants for aid, since a majority of them will be men and women of enthusiasm and promise merely rather than of demonstrated ability to carry researches to successful conclusions.

In weighing this matter the educational value of such widely scattered aid should not be overlooked. Many a meagerly equipped laboratory or library may be thus strengthened and many young men and women may be thus trained for work of research. The possession of a piece of apparatus, or a rare volume, or the opportunity to pursue early in life a year or two of uninterrupted scientific investigation, is, doubtless, of inestimable value to a few individuals. But the obvious objection to such a disposition of resources is that it serves only to supplement the educational work of colleges and universities. They already occupy this field, and it appears unwise as well as unfair to encroach on their domain even in a supplementary way. A less obvious objection is that arising from the diverse interests and the divided responsibilities which such a course entails. It may be observed

also that as regards themselves the experience of colleges and universities appears to be inimical to such a course, for we have not heard of any of them proposing to use its income, or any considerable share thereof, in building up departments of educational work in other institutions. But the fundamental objection to such a disposition of funds is that it promotes research only indirectly, whereas the primary object of a research institution should be to promote research directly. A research institution should aim to take up investigations which, by reason of their expense or magnitude, are not likely to be carried to completion in other ways. And in the pursuit of this work it should be free to choose the best ways and means; it should not be hampered by a host of applicants backed by endless recommendations of doubtful validity.

Thirdly, that the Institution may advantageously limit much more narrowly than hitherto the award of minor grants. It should seek to eliminate the amateur, the dilettante, and the tyro as far as possible from the list of eligible applicants, and concentrate attention chiefly on those who have already demonstrated ability to produce results. This policy will restrict the range of operations of the Institution to some extent, but it will diminish the hazard to a greater extent, and will permit a degree of thoroness of work not otherwise attainable.

One of the most serious objections to giving aid to numerous small projects lies in the fact, amply shown by experience, that the estimates of the cost thereof are generally vague and almost always too small for the accomplishment of good work. Many, if not most, authors of such projects proceed without plans and specifications, often ignoring somewhat contemptuously such estimates of cost and probable outcome as may be supplied in most cases by judicious forethought. The projects are so small that it does not appear essential to individual investigators to consider carefully their cost and bearing. Indeed, only investigators of considerable experience are able to use adequate forethought in this respect. But when one contemplates not a single small project, but the aggregate of a large number of them, the need for carefully drawn plans, specifications, and estimates is seen to be as important as in the case of any large project.

By limiting the fields of activity in this direction it will be possible for the Institution not only to make a choice amongst promising investigations, but likewise to make a choice amongst tried investigators. This appears to me to afford a workable compromise also between the extremes of a limited number of large projects and an unlimited number of small projects—a compromise whereby the essential advantages of both extremes may be secured and their inherent disadvantages avoided.

But while it appears desirable to limit the range of activity of the Institution at any epoch, it appears still more desirable to insist on a high standard of efficiency determined by the quality and the quantity jointly of results

attained. To secure this end the Institution must not only seek to aid mainly eminent investigators, but it must seek to aid them for such periods and to such an extent that their best efforts may be enlisted. The grantee should be able to feel that his connection, tho temporary, with the Institution is creditable, and, reciprocally, that the aid he accepts implies higher obligations than those attaching to an educational scholarship or fellowship. In many cases within the experience of the Institution grantees appear to have regarded the system of small grants as a sort of lottery, involving neither credit to nor responsibility from either party to an award. Experience of this and similar kinds is inevitable, however, in the formative stages of the Institution; for the distinction between a research institution and an educational institution is not yet so clearly defined that contemporary society can avoid attributing to the former the eleemosynary function which is being slowly eliminated from the latter.

In conformity with the views here set forth the President is disposed to recommend that in general minor projects be aided only when they can be carried on by investigators of known competence; that such investigators become for the time being affiliated to and advisers of the Institution, and that they be designated as Research Associates of the Institution. The periods of affiliation of such associates must be determined, of course, by the circumstances of individual cases. But it may be observed that as a rule these periods will be from two to five years, or more, since few investigations well worth undertaking by the Institution can be brought to satisfactory conclusions in shorter intervals of time.

Mode of Development of Institution.

It appears worthy of note, from the point of view of evolution, that the Institution finds itself occupied with two principal divisions of activities, namely, those arising from its internal affairs and those arising from its external affairs. On the one hand, we are busily engaged with many investigations, in many diverse fields, carried on under widely varying conditions. On the other hand, we are equally busily engaged with a multitude of external relations which are usually more or less conflicting and often incompatible. Thus the development of the Institution may be likened to the struggle of an organism which is trying at once to discover its proper functions and to adjust itself to the conditions of its environment.

It is worthy of note, also, from the same point of view, that this struggle is inevitable to a great degree, and that it is only out of the resulting chaos of opinions as to ways, means, and methods, and out of the experience of the Institution itself, that definite and approved lines of action and policy may be attained.

In view of these circumstances, it seems essential to warn our allies of the academic world and the public at large against the danger of expecting more from the Institution than is possible of accomplishment in a limited

time and with a limited income. Altho the work of the Institution is in a peculiar degree novel and untrammeled, it is yet subject, properly enough, to the restrictions set by human experience and by contemporary society. Hence, if the reviewer of the Year Books finds reason to complain of a bewildering array of technical details, he should reflect that this array is far less than a host of investigators would like to have it. If the humanist or the scientist finds reason to complain that little or no aid has been given to him or to his special field of research by the Institution, he may derive comfort from the fact that he is one of an overwhelming majority necessitated by the limitations of available resources. And if the bibliophile has found reason for dissatisfaction in the distribution of the publications of the Institution, he may be disposed to be lenient with the latter on learning that he is one of many thousands soliciting favors.

Out of this plexus of internal and external relations and interrelations it is the duty of the administrative branch of the Institution to evolve, so far as practicable, such a degree of order and system as will best promote productive and thoro work of research, and at the same time to restrict, so far as practicable, an unproductive or wasteful expenditure of energy and resources. Altho progress towards an adequate fulfilment of this duty must be of necessity slow in order to be sure, it is believed that distinct advances are accumulating, and that the obvious difficulties and dangers which beset the development of so novel an institution are only such as may be overcome by a reasonable application of time and patience.

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

In accordance with the by-laws of the Carnegie Institution of Washington, Article V, Section 3, and Article VI, Section 3, the Executive Committee herewith respectfully submits its report for the year 1905–1906.

During the fiscal year ending October 31, 1906, the Executive Committee held eight meetings. Printed reports of these meetings have been sent to the members of the Board of Trustees.

Immediately on the adjournment of the Board of Trustees, December 12, 1905, the members of the Executive Committee met and organized by electing Mr. Wright temporary chairman, and Mr. Walcott temporary secretary. At the meeting of the committee on the 9th of January, 1906, Mr. Wright was made chairman for the current year, and it was voted that Mr. Walter M. Gilbert, Assistant Secretary of the Institution, act henceforth as secretary of the committee.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1905–1906, together with various recommendations and suggestions. The interpretation of the by-laws, as stated in the last annual report of the Executive Committee relative to such report and the President's report, and to which no objection has been made, is again adopted, and the committee hereby presents the President's report as its own and with its approval.

There is also submitted, on the following pages, a cash and financial statement.

Carroll D. Wright, *Chairman.*
John S. Billings.
Cleveland H. Dodge.
Daniel C. Gilman.
S. Weir Mitchell.
Elihu Root.
Charles D. Walcott.
Robert S. Woodward.

Washington, D. C., *November, 1906.*

Cash Statement of Receipts and Disbursements Since October 31, 1905.

RECEIPTS.

INTEREST:		
U. S. Steel Corp. bonds	$500,000	
A. T. & S. Fe Ry. "	4,000	
N. Pac. Ry. Co. "	4,000	
N. P. Gt. N. "	2,000	
Central Pacific "	2,000	
L. S. and Mich. S. "	2,000	
Deposits in banks	13,304.47	
		$527,304.47
SALES OF PUBLICATIONS:		
Index Medicus	2,970.56	
Year Book	37.60	
Miscellaneous	1,341.52	
		4,349.68
REFUND ON GRANTS		2,395.25
SUNDRIES		19.44
		534,068.84
Balance from last report to Trustees, Oct. 31, 1905		468,295.92
		1,002,364.76

DISBURSEMENTS.

INVESTMENT:		
Building site		$63,015.09
GRANTS:		
Large	$381,972.37	
Minor	84,426.27	
Research assistants	8,749.99	
		475,148.63
PUBLICATION		42,431.19
ADMINISTRATION:		
Trustees	1,777.26	
Executive Committee	918.17	
Advisory Committees	627.69	
Salaries	24,688.67	
Temporary employees	2,222.55	
Insurance and surety	207.78	
Rent and telephone	3,850.43	
Furniture	800.65	
Office supplies and stationery	2,183.42	
Postage, express, &c.	2,766.44	
Printing	2,491.84	
		42,534.90
INDEX MEDICUS (VOL. I, '03)		86.99
		623,216.80
CASH IN BANKS:		
U. S. Trust Co., N. Y	362,868.62	
Nat. City Bank, N. Y	10,798.46	
Am. S. & T. Co., D. C	5,480.88	
		379,147.96
		1,002,364.76

Financial Statement.

		ASSETS.	LIABILITIES.
Endowment			$10,000,000.00
Reserve fund and accrued interest			280,876.80
Bonds (original cost):			
U. S. Steel Corporation bonds, 5%		$10,000,000.00	
$100,000 A., T. & S. Fe Ry. Co. Genls. Mtg. 4% 100-year gold bonds, Oct. 1, 1995		100,112.50	
$100,000 N. P. Ry. Co. Prior Lien Ry. and Land Grant gold bonds, Jan. 1, 1997		101,800.00	
$50,000 N. P. G. N. 4% Joint Bonds Chic., B. and Q. Collateral, July, 1921		46,500.00	
$50,000 L. S. & Mich. S. Ry. 4% debenture bonds		48,222.22	
$50,000 C. Pacific First Refunding gold 4% bonds		51,937.50	
Real Estate and Equipments:			
Furniture (75% of cost)		4,342.24	
Department of Botanical Research:			
Office—Library	$831.45		
Apparatus	1,656.15		
Buildings	5,710.44		
Grounds and fencing	3,104.52		
		11,302.56	
Department of Experimental Evolution:			
Buildings	$21,347.31		
Equipment, apparatus, &c	1,854.50		
		23,201.81	
Department of Geophysical Research:			
Office	$2,242.06		
Laboratory	14,385.64		
Shop	1,365.01		
Site	17,500.00		
		35,492.71	
Department of Marine Biology:			
Vessels	$9,832.63		
Buildings and docks	7,375.78		
Apparatus	519.36		
Furniture	827.72		
		18,555.49	
Solar Observatory:			
Buildings	$38,159.00		
Instruments and equipments	99,367.63		
		137,526.63	
Department of Terrestrial Magnetism:			
Office equipment	$1,742.79		
Instruments	8,166.13		
Vessel equipment	2,093.99		
		12,002.91	
Site for administration building		63,015.09	
Property investment (aggregate cost)			242,424.35
Grants:			
Large			248,520.37
Minor			78,716.67
Research assistants and associates			22,283.34
Publication			54,262.42
Administration			17,868.50
Cash		379,147.96	
Unappropriated fund			88,207.17
		11,033,159.62	11,033,159.62

RESEARCH ASSOCIATES AND ASSISTANTS.

The policy in relation to research assistants, as outlined in Year Book No. 2, pp. xlvii–xlviii, was continued, and the persons named below pursued investigations during the year, or for a portion of the year, in the branches of science indicated. The total amount allotted to date for each investigation is appended.

*ACREE, SOLOMON F., Johns Hopkins University, Baltimore, Md. Grants Nos. 204 and 372. Studies of pinacone-pinacolin rearrangement and of urazales.	$1,300
BLAKESLEE, ALBERT F., Harvard University, Cambridge, Mass. Grants Nos. 160 and 340. Investigation of sexuality in lower fungi	2,000
FARRAR, CLARENCE B., Sheppard and Enoch Pratt Hospital, Baltimore, Md. Grants Nos. 163 and 350. Experimental studies on structure and functions of the cerebral cortex, its histopathology and physiological psychology	2,000
FERGUSON, WILLIAM S., University of California, Berkeley, Cal. Grant No. 338. Completion of "A History of Athens from Demosthenes to Plutarch"	1,200
FRANZ, SHEPHARD I., Hanover, N. H. Grant No. 80. Functions of the cerebrum with special reference to the functions of the association areas	1,000
JOHNSON, ROSWELL H., State Normal School, Cheney, Wash. Grants Nos. 274 and 339. Researches upon Hippodamia and other lady-beetles as a member of staff of Department for Experimental Evolution	2,100
JONES, WILLIAM, American Museum of Natural History, New York, N. Y. Grants Nos. 173, 283, and 316. Religion of central group of Algonkin Indians	3,000
LOUDERBACK, GEORGE D., Reno, Nev. Grants Nos. 66 and 67. Basin Range structure and glaucophane and associated schists of California and Nevada	2,300
MORSE, ALBERT P., Wellesley, Mass. Grants Nos. 84 and 284. Research on North American Acridiidæ, with especial reference to biology, distribution, and variation	2,000
†OLIVE, EDGAR W., University of Wisconsin, Madison, Wis. Grants Nos. 32, 132, and 271. Researches on the life histories and cytology of certain lower plants	3,000
ROWE, LEO S., University of Pennsylvania, Philadelphia, Pa. Grant No. 144. Study of the political system of the Argentine Republic	1,500
RUSSELL, HENRY N., Princeton University, Princeton, N. J. Grants Nos. 88 and 207. Determination of stellar parallaxes by photographs	2,000
SCOTT, GEORGE W., Cosmos Club, Washington, D. C. Grants Nos. 60, 141, and 275. The history and law of private pecuniary claims against the state (principally foreign nations to which the United States has been a party)	3,900
ZAHM, ALBERT F., Catholic University of America, Washington, D. C. Grant No. 272. Determination of resistance of air to moving bodies	1,000
ZERBAN, FRITZ, College of the City of New York, New York, N. Y. Grants Nos. 169 and 273. Investigation of rare earths. Assistant to Prof. Baskerville	2,000

* Grant 372 was not designated as a "research assistantship."
† Grants 32 and 132 were not designated as "research assistantships."

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED BY GRANTEES AND ASSOCIATES.

Under this heading it is sought to include the titles of all publications bearing upon the work done under the grants from the Carnegie Institution of Washington. In the list for the past year, as shown below, there may be some omissions, although it has been the endeavor to make it as complete as possible, and in some cases titles may be included which have only an indirect connection with such work. A list of works published by the Institution during the year will be found in the President's report on page 31.

ACREE, S. F., Johns Hopkins University, Baltimore, Md. On a formaldehyde color test for proteids. (American Chemical Journal.)
——, and HINKINS, J. E. On abnormally acid saliva. (Journal of Biological Chemistry.)
——, ——. On the composition of human teeth. (Journal of Biological Chemistry.)
ADAMS, F. D., and COKER, E. G., McGill University, Montreal, Canada. An investigation into the elastic constants of rocks, more especially with reference to cubic compressibility. (American Journal of Science. Aug., 1906.)
ADAMS, WALTER S., Solar Observatory Office, Pasadena, Cal. Some notes on the H and K lines and the motion of the calcium vapor in the sun. Contributions from the Solar Observatory No. 6. (Astrophysical Journal, v. XXIII. Jan., 1906.)
——. Sunspot lines in the spectrum of Arcturus. Contributions from the Solar Observatory No. 12. (Astrophysical Journal, v. XXIV. Sept., 1906.)
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ALLEN, E. T., WHITE, W. P., and WRIGHT, F. E. On wollastonite and pseudo-wollastonite polymorphic forms of calcium metasilicate. (American Journal of Science, v. XXI, No. 122, pp. 89–108. Feb., 1906.)
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AYERS, S. A. See DUERDEN, J. E.
BANKS, ENOCH M., Newnan, Ga. The economics of land tenure in Georgia. (Columbia University Press, Macmillan Co. 1905.)
BARROWS, W. N. See CASTLE, W. E.
BARUS, CARL, Brown University, Providence, R. I. Condensation nuclei. Presidential address. (Physical Review, v. XXII, pp. 82–110. Feb., 1906.)
——. Condensation nuclei in alcohol vapor. (Amer. Jour. of Science. Aug., 1906.)
——. Condensation nuclei in carbon dioxide and in coal gas. (Physical Review. Aug., 1906.)
——. Corpuscular radiation from cosmical sources. (Science, v. XXIII, p. 952. 1906.)
——. Eigenschaften von Kondensationskernen, etc. (Physikalische Zeitschrift, No. 21, pp. 718–726. 1905.)
——. Translation by E. Bloch. Les noyaux de condensation. (Le Radium, pp. 18–20. Jan., 1906.)
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BATESON, WILLIAM, and GREGORY, R. P. On the inheritance of heterostylism in *Primula*. (Proc. Royal Soc. B., v. 76, pp. 581–586. 1905.)
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——, ——, ——. Experimental studies in the physiology of heredity. (Report 3 to the evolution committee of the Royal Society. 53 pp. London, 1906.)
BAUER, L. A. Cheltenham Magnetic Observatory registration of effects from electric cars over 12 miles or 20 kilometers distant. (Terrestrial Magnetism, v. XI, No. 1, Mar., 1906, pp. 53–56.)
——. Inauguration of the magnetic survey of the North Pacific Ocean. (Science, v. XXII, No. 562, Oct. 6, 1905, p. 443.)
——. Magnetic survey of the North Pacific Ocean: Instruments, methods, and preliminary results. (Terrestrial Magnetism, v. XI, No. 2, June, 1906, pp. 65–92.)
——. Magnetic survey of the Pacific Ocean. Route of second cruise. (Terrestrial Magnetism, v. XI, No. 1, Mar., 1906, p. 52.)

BAUER, L. A. On the present shrinkage of the earth's magnetism. (Physical Review, v. XX, 1905, p. 126.)
———. Report of Department of Research in Terrestrial Magnetism. (Year Book Carnegie Institution of Washington No. 4, 1905, pp. 264–274, pl. 7.)
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BAXTER, G. P., Boylston Hall, Cambridge, Mass. A revision of the atomic weight of bromine. (Proc. Amer. Acad. of Arts and Sciences, v. 42, pp. 201–214. Aug., 1906.)
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BYALL, J. BRUCE, Cincinnati, Ohio. The American system of improving and administering commercial facilities. (Annals American Academy of Pol. and Soc. Sc. Nov., 1904.)
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REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1905–1906 but others on which work has been continued from prior years.

ANTHROPOLOGY.

Jones, William, American Museum of Natural History, New York, N. Y. Grant No. 316. *Investigation of the religion of the Central Algonkin Indians.* (For previous report see Year Book No. 4, p. 53.) $1,000.

The work of the past year has been among the Ojibwa, as it was during the year before. Most of the time has been devoted to the translation of the mass of native texts which had previously been obtained. The work of translating has been slow; but, now that it is drawing to a close, the main results of the investigation should be ready for publication in a short time. The paper will contain myth, tradition, an account of the leading religious ceremonies, and a treatment of certain fundamental elements at the basis of Ojibwa religious belief.

Dorsey, George A., Field Museum of Natural History, Chicago, Illinois. Grant No. 315. *Investigation among the tribes of the Caddoan stock.* (For previous reports see Year Book No. 2, p. xv, Year Book No. 3, p. 83, and Year Book No. 4, p. 53.) $3,000.

Abstract of Report.—The work done during the year 1906, the fourth year of the investigation, has been a continuation of that done in previous years among the tribes of the Caddoan stock. The investigation of the mythology of the tribes comprising this stock has been completed, and in June was submitted the manuscript of the last volume bearing on this subject, the title being "Mythology of the Pawnee." This volume will soon be issued as one of the publications of the Carnegie Institution of Washington. The volume contains many tales of the Chaui, Kitkehahki, and Pitahauirat bands of the Pawnee and certain tales of the Skidi which, for certain reasons, had not been printed in the memoir on the "Traditions of the Skidi Pawnee." As a supplement to the volume, forming indeed Part II, there is now being prepared the texts of the songs which belong to the volume and the results of an exhaustive account made of a comparative study of the mythology of the Caddoan tribes with those of their neighbors. The preliminary work of this Part II has been completed and will be ready for publication some time within the coming year. The greater part of the year has been spent in preparing a manuscript of an extensive account of the society and religion of the Skidi Pawnee. The preparation of this manuscript is about three-fourths completed, the data for the remainder having been practically all secured. The greater part of the volume will be devoted to as full an account as it has been possible to obtain of the religious ceremonies of the Skidi, the obtaining of the material for this work having been in progress for the last five years. It is believed that practically all of the rituals now known among the Skidi have been obtained. Many of the rituals, however, are upon phonographic cylinders, upon which they were recorded, and will require translation and much careful study. Some difficulty has been found in securing an investi-

gator competent to consider the question of the music of the ceremonies. To look after this part of the investigation Dr. von Hornbostel, of the University of Berlin, has been invited to come to Chicago to make a careful examination of the music and report on it. He is at the present time in Chicago engaged in this work, and some interesting results are looked for. A volume of texts has been carefully planned. Much material has already been secured for this volume, and its scope has been so planned as to make it of value not only to ethnologists but especially to students of psychology and linguistics.

ARCHEOLOGY.

American School of Classical Studies at Athens. James R. Wheeler, Chairman of Managing Committee, Columbia University, New York, N. Y. Grant No. 317. (*a*) *Maintenance of a fellowship in architecture at Athens*, $1,000. (*b*) *Excavation on the site of ancient Corinth and exploration*, $1,500. (For previous report see Year Book No. 4, p. 54.) $2,500.

(*a*) Mr. Gordon Allen, A. B., who held this fellowship during the past year, has undertaken the careful preparation of drawings of the ancient Sanctuary of Æsculapius, on the south slope of the Acropolis. In this work he has been greatly assisted by Mr. O. M. Washburn, fellow at the school of the Archeological Institute, and Mr. L. D. Caskey, secretary of the school.

The Aclepicum, though excavated a good many years ago, has never been carefully studied from the architectural point of view, and no adequate drawings of the sanctuary have ever been published. It therefore seemed a good thing to the authorities of the school to have such drawings made, with the idea that they should later be published in connection with descriptive text and an account of the cult of Æsculapius at Athens. Mr. O. M. Washburn has undertaken the preparation of such an account, and it is hoped that publication may follow in due course, though this unfortunately depends on the rather limited financial resources of the school. Mr. Allen's drawings are reported to be finished and to be of excellent character.

(*b*) The excavation work of the school has not been carried on during the present year, owing to the recent death of the Director, which forced upon the managers a temporary organization for the year. There is therefore no report to make under this head.

American School of Classical Studies in Rome. Andrew F. West, Chairman of Managing Committee, Princeton University, Princeton, New Jersey. Grant No. 318. . (*a*) *Maintenance of two research fellowships in classical archeology*, $1,600. (*b*) *Publication of results of scientific investigation*, $1,000. (For previous report see Year Book No. 4, p. 54.) $2,600.

(*a*) Mr. Albert William Van Buren, of Yale University, and Miss Susan Helen Ballou, of the University of Chicago, held the fellowships for the year 1905–1906.

Abstracts of Reports.—Mr. Van Buren's report relates particularly to his studies in topography, epigraphy, and paleography. The results of investigations carried on by Mr. A. S. B. Wace and Mr. Van Buren at Demetrias in Thessaly have been incorporated in an article which appeared in the Ath. Mitteilungen for 1905. An account of the remainder of their Magnesian journey has been prepared by Mr. Wace for publication in the Journal of Hellenic Studies. Various periods of construction visible in the temples of Castor and of Concord in the Roman Forum have been investigated, and a preliminary statement of results was published in the Berliner Philologische Wochenschrift for January 27, 1906. A fuller account will probably be published in the Classical Review for February, 1907. Mr. Van Buren also conducted six Campagna excursions of the American School, and lectured informally on the sites and monuments visited. Work on a monograph on Ostia was delayed and finally abandoned because the work was being undertaken by other agencies.

An article on "Stamps on Bricks and Tiles from the Aurelian Wall at Rome," done in collaboration with Dr. Pfeiffer and Professor Armstrong in 1902–1903, and a paper on "The Text of Columella," written in 1903, have appeared in volume I of the School Papers. An article on "Greek Inscriptions from Asia Minor, Cyprus, and the Cyrenaica" has been submitted for publication among the Papers of the School, and some notes on "Inscriptions from Sinope" will be published in the Journal of the Archeological Institute. Papers on the "Inscription of the Charioteer Menander," recently obtained by Professor Norton; "A Bronze Statuette from Norba," and "A Marble Frieze from Side" have been submitted for publication in volume II of the School Papers.

In the Classical Review for 1905 Mr. Van Buren published a "Note on Pliny, Epp. III. 6, IX. 39," and now has in preparation an article on the water supply of ancient Rome and a catalogue of all the inscriptions at the American School.

Miss Ballou has been working upon a collection of the Scriptores Historiæ Augustæ. The first draft has been thoroughly revised with reference to the Palatine and Bamberg manuscripts and by comparison with other manuscripts in Florence, Milan, and Paris. Surmises in regard to the extent to which Plutarch worked over and emended the Palatine have been confirmed by this second examination. Continual work in this field has postponed a contemplated work on the palimpsest of Aulus Gellius. Two days were spent at Monte Cassino in the collation of the "Liber de Locis Sanctis" of Pietrus Diaconus, a manuscript of the 12th century, in very bad condition.

(*b*) No publications have yet been issued under these grants, but the preparation of a new volume of School Papers is progressing under the editorial supervision of Prof. John C. Rolfe, of the University of Pennsylvania. This volume will contain papers of original scientific interest, prepared by members of the school.

Brigham, William T., Bernice Pauahi Bishop Museum, Honolulu, Hawaii. Grant No. 341. *Surveying, photographing, and describing the heiau, or ancient stone temples of the Hawaiians, in connection with a treatise on "Ancient Hawaiian Worship."* $2,500.

Abstract of Report.—Under the grant to aid in the exploration and study of the ancient Hawaiian temples, or heiau, the available time of the grantee has been devoted to compiling lists of all known remains, checking all that are wholly destroyed, and selecting those in such condition as to give valuable data as to construction or use. Mr. John F. G. Stokes, curator of Polynesian ethnology in the Bishop Museum, has undertaken the careful survey and location of these temples and has already done much work on the island of Oahu and on Hawaii, where he is now surveying. He has largely increased the list of known temples, but many of the new ones and not a few of the earlier ones on the list are so far ruined that it is not desirable to do more than make a mere statement of their former existence and the kings or chiefs by whom erected. On the other hand, the process of clearing away the vegetation which has protected many from destruction has revealed interesting facts in the astonishing variety of plan and the great variation in extent of Hawaiian temples.

It has been found that in some of the principal temples prayers are still offered, and the last king, not more than a score of years ago, made a large and formal offering to the war god of an ancient temple on Kauai. In former years offerings in the apparently deserted place of ancient worship were found. Dr. Brigham has, by the excavations and clearings already made, found confirmation of his knowledge of the ancient ritual obtained by him forty years ago from a priest who had offered human sacrifices and conducted the worship in one of the more important of the temples of the island of Molokai.

He has made or obtained photographs of all known existing idols of Hawaiian origin, and with the additional information obtainable as this exploration goes on he hopes to present a fairly clear picture of the worship of this, the most religious people of the Pacific region.

The expenditures so far have been for travel and labor in clearing and not for permanent instruments or apparatus, for the trustees of the Bernice Pauahi Bishop Museum have kindly loaned instruments for the survey and have arranged for the assistance of members of the museum staff; among these Mr. Stokes, who has camped with Dr. Brigham in such temples as are best preserved, is giving invaluable aid. The grantee hopes to present next year the finished results of his studies of the religious side of this remarkable people, who, like the Hebrews, had places of refuge, public temples of vast size, and also divinity schools, a powerful priesthood (still existing), and oratories in every house. In their best estate the Hawaiians kept their "forty thousand and four hundred thousand gods" fully employed.

Müller, W. Max, Philadelphia, Pennsylvania. Grant No. 355. *Continuation of Archeological Researches in Egypt.* (For previous report see Year Book No. 3, p. 84.) $2,000.

Dr. Müller pursued archeological researches in Egypt during the summer and fall of 1906. After working at the Cairo Museum for several weeks, he copied and photographed in the temples of Eastern Thebes. A fuller report will be forthcoming in 1907.

Pumpelly, Raphael, Newport, Rhode Island. Grant No. 229. *Trans-Caspian Archeological Expedition.* (For previous reports see Year Book No. 2, p. xxxiii; Year Book No. 3, pp. 75–79, and Year Book No. 4 p. 55.) $26,000.

Work upon the results of the expedition of 1904 has been pushed during the past year and the report is in press.

Ward, William H., 130 Fulton street, New York, N. Y. Grant No. 305. *Completion of study of oriental art recorded on seals, etc., from western Asia and Egypt.* (For previous reports see Year Book No. 2, p. xvii; Year Book No. 3, p. 85, and Year Book No. 4, p. 55.) $250.

Dr. Ward reports that he has met with unexpected delays in completing his work on oriental seal cylinders, but that the text is all written in seventy chapters, covering with great care the Babylonian, Persian, Assyrian, Syrian, Hittite, and Phenician art of Asia, but not the Egyptian, which has been provided for by other scholars. At present he is engaged, with the help of two artists, in completing the drawings, many of them hitherto unpublished, not only from his own collection of over a thousand cylinders, the majority of which have gone to the Metropolitan Museum in New York, but from the Louvre, the Bibliothèque Nationale in Paris, the British Museum, the Museum in Berlin, and other public and private collections. It has been his especial aim to study the mythological art of these cylinders and to identify both the gods represented and their emblems. Accordingly the cylinders are classified by their nationality, their period, and their subject, particular attention being paid to the archaic period, when motives were being developed and mythological ideas had not yet been conventionalized and fossilized into fixed forms. It has been a further purpose to show how the earliest forms in Chaldea, of more than 3,000 B. C., have been adopted and modified in Assyria, Persia, Syria, and Phenicia, and to learn what new elements have been successively introduced from Egypt or of native local origin. In order to give completeness to the work, it has been necessary to multiply the illustrations in the rarer scenes depicted, if important, giving all that are known, and in other cases showing the variations of type that were allowed.

ASTRONOMY.

REPORT ON THE SOLAR OBSERVATORY, MOUNT WILSON, CALIFORNIA.*

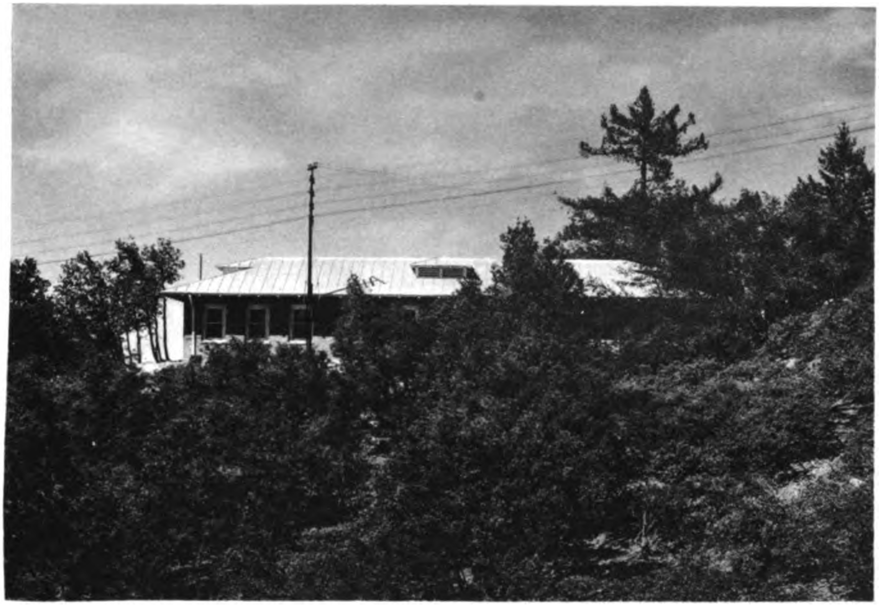
By George E. Hale, Director.

Two events of the past year, of special importance in their bearing upon the future work of the Solar Observatory, call for mention at the opening of this report.

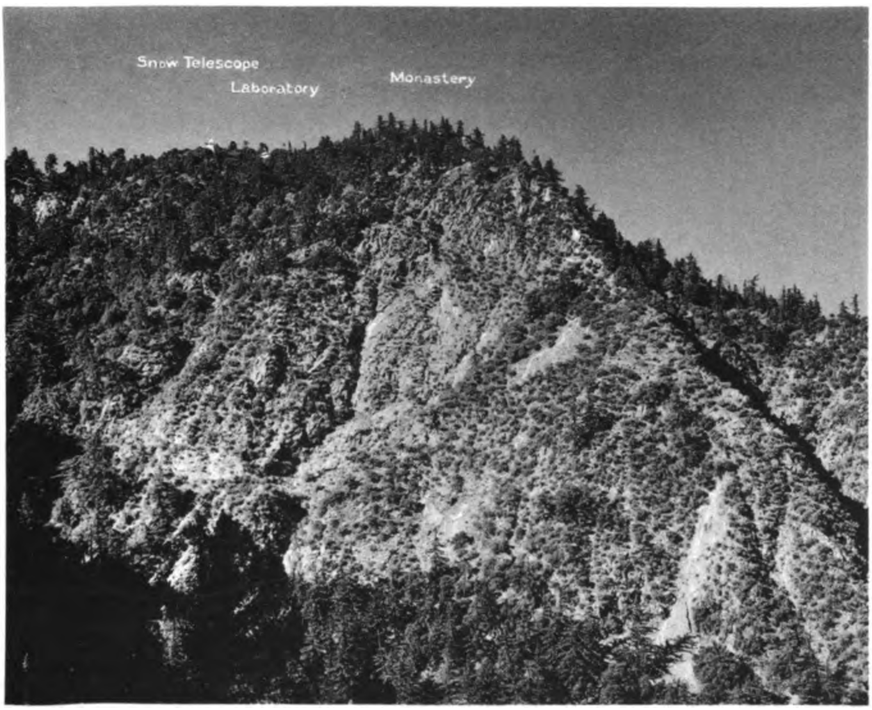
The first of these is the gift of $45,000, by Mr. John D. Hooker, of Los Angeles, to meet the cost of a mirror of 100 inches aperture and 50 feet focal length, for a great reflecting telescope. Such an instrument, which will collect about 2.7 times as much light as our 60-inch reflector, will permit the work of the Solar Observatory to be very greatly extended. Our plan of research, which is intended to provide for an effective attack upon the problem of stellar evolution, requires varied apparatus and the most powerful telescopes obtainable.

As stated in my previous report, the attack is along three converging lines, involving the study of the sun as a typical star; the study of stars and nebulæ and of their relationship to the sun and to one another; and the interpretation of both solar and stellar phenomena by means of carefully chosen laboratory experiments. In the laboratory work, our luminous sources are so far under control that we can usually adapt them to the requirements of the particular investigation. In other words, if a light source is only feebly luminous, we can ordinarily increase its brightness to such a degree as to permit its analysis by the most powerful spectrographs. In the case of the stars, however, we have no such means of controlling the conditions. It too often happens that the very stars which present the most interesting and important peculiarities—perhaps for the reason that they resemble the "missing link" of the naturalist, in view of their promise of uniting some broken chain of evidence—are so faint that an adequate analysis of their light is impossible. A 100-inch reflector, with its immense light-collecting power, will obviously be of the greatest advantage in just such cases. A similar illustration is afforded by the spiral nebulæ. Only a few of these remarkable objects are large enough, and bright enough, to lie well within the range of existing photographic telescopes. Even in these the changes in form are so slow that none have ever been detected by existing means. Hundreds of thousands of smaller nebulæ of this type, although the remarkable fact of their existence and spiral form has been discovered with the Crossley reflector, are so minute on the photographic plate that little can be learned of their true

* For the year ending September 30, 1906. Grant No. 314. $150,000 for construction and maintenance. (For previous reports see Year Book No. 3, pp. 154-174, and Year Book No. 4, pp. 56-77.)



SPECTROSCOPIC LABORATORY, MOUNT WILSON.



MOUNT WILSON FROM MOUNT HARVARD.

nature. A 100-inch reflector, with a focal length of 50 feet, should be capable of photographing an immense number of these objects to excellent advantage. In view of the work of Chamberlin and Moulton on the nebular hypothesis, and the theoretical study of spiral nebulæ upon which the latter is engaged, such observational evidence as the new instrument may afford should prove of the greatest value. Mr. Hooker's gift is especially opportune, in that it will permit the Solar Observatory to continue, after the completion of our 60-inch reflector, the employment of the skilled opticians who have been trained by Mr. Ritchey for their difficult and delicate work. The question as to the type of mounting to be employed, and the various details of its design, need not be considered until the 60-inch reflector has been thoroughly tested in actual use on Mount Wilson. The completion of the optical work can not be expected before the end of four years, while only a year would be required by the Union Iron Works Company to complete the mounting and dome. The liberal terms of Mr. Hooker's letter of gift specifically free the Carnegie Institution from any obligation whatever in accepting the mirror. The source from which the funds are to be obtained to mount and house it is not known, but it may be anticipated with confidence that a donor can be found when the proper time arrives. I have discussed elsewhere in this report the various questions that naturally suggest themselves as to the probability of obtaining success with so large a reflector.

The second event to which I wish to allude is the formulation and preliminary test of the hypothesis that the characteristic phenomena of the spectra of sun-spots may be accounted for on the assumption that the temperature of the metallic vapors within sun-spots is below that of the corresponding vapors in the sun's reversing layer. The spectra of sun-spots have for many years offered an interesting problem to solar physicists. The fact that some of the lines of certain metals are greatly strengthened in them, while others are weakened or obliterated, has given rise to much speculation as to the probable cause of these phenomena. The strengthened and weakened lines have appeared to be set apart, in a most capricious manner, from the unaffected lines of the elements in question, though certain solar observers have been inclined to regard spot spectra as indicating merely an increase in the absorptive phenomena visible at all points upon the solar surface. While it can not be said that our hypothesis has advanced beyond the first stage, it has nevertheless been demonstrated in our laboratory work that the great majority of lines that are strengthened in sun-spots are also strengthened in the laboratory when the temperature of the vapor which gives rise to them is decreased, while a similarly large proportion of the lines that are weakened in sunspots are weakened in the laboratory under the same conditions. The

possibility that agencies other than mere change of temperature are concerned is not entirely excluded, but the present indications are favorable to the view that the assumption of a lower temperature will prove to be the simplest means of accounting for the phenomena. This view is based not merely upon an extensive series of laboratory experiments, but upon various other criteria, one of the most important of which is the fact discovered in the course of our recent investigations, that spectroscopic phenomena resembling in the closest degree those observed in sun-spots are apparently characteristic of certain stars which in all schemes of stellar evolution are classified as cooler than the sun. This fact is of special significance in its bearing upon the broader applications of our sun-spot investigations. It illustrates the truth that the correlated study of solar, stellar, and laboratory phenomena offers a most promising means of attacking the problem of stellar evolution. It is now evident that the investigations we have begun on the spectra of sun-spots, and partially interpreted through laboratory experiments, are likely to serve as our surest guide in those more general investigations of stellar phenomena which it is our prime object to undertake.

Of the other events of the year, which are discussed more specifically in the body of this report, certain ones call for general comment here. The destructive earthquake of April 18, from which our colleagues of the Lick Observatory so fortunately escaped, naturally raised apprehensions as to the fate of the mounting of our 60-inch reflector, then approaching completion at the Union Iron Works in San Francisco. It was some time before definite knowledge of the facts could be ascertained. It was then learned that, although the Union Iron Works were outside of the great fire zone, the direct effects of the earthquake shock within their grounds were very serious. Nevertheless, the reflector mounting wholly escaped injury, though by the barest of margins. The heavy labors of reconstruction, together with subsequent strikes, interfered so seriously with the completion of the mounting that it has only recently been delivered to us in Pasadena. It is now being erected, and the extensive work to be done upon it by our machinists will occupy them for fully a year. It is our hope that this work may be completed in time to permit the telescope to be set up on Mount Wilson in the autumn of 1907. The polishing of the mirror, like all of the other important work of the optical and instrument shops, has proceeded most satisfactorily under Mr. Ritchey's direction. At the present time the figure of the mirror has reached a high degree of perfection, but it will be still further improved before it is regarded as satisfactory.

Thanks to the assistance and cooperation of President Woodward, the long-standing problem of a road up Mount Wilson has at last been satis-

factorily solved. A decision on this subject was necessarily long delayed, in the hope that a project for the construction of a railway to the summit, by the owners of the Mount Wilson Hotel, might permit us to avoid the serious expenditure which the widening of the trail must involve. A survey of the proposed railway was undertaken during the winter, but it did not become clear until June that the hope that the railway might be constructed within a reasonable time must be definitely abandoned. The conclusion that it would be necessary to proceed independently has been fully confirmed, as nothing appears to have been done on the railway project since last spring. During President Woodward's visit to the Solar Observatory in June it was decided, on his recommendation, to employ Mr. Godfrey Sykes, of the Department of Botanical Research, as superintendent of the work of widening the "New Trail," which we had formerly used for "packing" with animals and for the operation of the small carriage on which our heavy machinery and instruments had been taken to the summit of the mountain. As stated elsewhere, the widening of the trail has proceeded rapidly under Mr. Sykes's direction, and is now nearly half completed. It is hoped that the road may be practically finished before the rainy season seriously interferes with the work.

The work of investigation during the year has been done with the aid of the Snow telescope, equipped with the large spectroheliograph and the Littrow spectrograph mentioned in the last annual report, and in the laboratory, which was finished and equipped early in the winter. Through the friendly cooperation of the University of Chicago, and of Prof. E. B. Frost, director of the Yerkes Observatory, the Solar Observatory was permitted to continue its use of the Snow telescope. Later the possibility of purchasing the instrument presented itself, and received the full approval of Miss Snow and of the university authorities. In announcing the purchase of the Snow telescope and its accessory apparatus from the Yerkes Observatory, at the original cost of construction, I wish to put on record the thanks of the Solar Observatory to Miss Snow and to Professor Frost, and to the acting president and trustees of the University of Chicago, for their courteous consideration of the matter, and for their acquiescence in the view that the transfer of the instrument would result advantageously, on account of the excellent atmospheric conditions at Mount Wilson and the facilities provided there for the adequate use of the telescope.

The 5-foot spectroheliograph, constructed in our instrument shop, has exceeded our expectations. During a considerable part of the rainy season, when the observations were necessarily much interrupted, it was employed for experimental purposes, which were completed in time to permit routine work to be undertaken on the return of good weather

in the spring. The sun is now photographed every clear morning and afternoon with this spectroheliograph, the daily record comprising photographs taken with the calcium, hydrogen, and iron lines, together with photographs of the chromosphere and prominences in calcium light. In the computing division, organized during the latter part of the year and placed under the direction of Mr. W. S. Adams, provision has been made for the measurement and reduction of these plates. The globe-measuring machine, with which the heliographic latitude and longitude of any point on the sun's disk can be read off directly, thus avoiding the long computations ordinarily required in such work, has been tested and perfected and is now in regular use. It proves to be capable of giving results of high precision, and saves the services of several computers. Further studies of spectroheliograph plates have been made with the aid of the stereocomparator. These studies have led to some conclusions regarding the comparative level of the calcium and hydrogen flocculi which are described elsewhere in this report.

Excellent photographs of sun-spot spectra have been obtained with the aid of the Littrow spectrograph, and these have served, in connection with our laboratory studies, in the investigation of the cause of the characteristic phenomena of spot spectra. The same instrument has been used by Mr. Adams in a spectrographic investigation of the solar rotation, which has already yielded excellent results.

The work of our spectroscopic laboratory, of which Mr. Gale has been placed in charge, has proved to be of the greatest value in the interpretation of our solar observations. The need developed in our sun-spot investigations for a 50 K. W. electric furnace has made it necessary to fit up such a furnace, as well as a simple but powerful Littrow spectrograph, in our Pasadena building, because our present power plant on Mount Wilson is not capable of giving so large a current.

A word should be said as to our further tests of the atmospheric conditions on Mount Wilson. The experience derived in three successive seasons has left no doubt of the remarkably high quality of the definition, both for solar and stellar investigations. During the rainy season, as might be anticipated, the definition on the clear days is similar to that experienced under like conditions in the eastern part of the United States. Soon after the close of the rainy season, however, when the weather has settled down to that condition of serenity which is so characteristic of California summers, the average definition is remarkably high. The purity of the sky and the perfect calm of many of the nights promise much for the performance of the 60-inch and 100-inch reflectors.

The Solar Observatory is glad to take part in the work of the International Union for Cooperation in Solar Research, which was definitely

organized last summer at Oxford. A plan of cooperation in work with the spectroheliograph has been perfected, involving the use of instruments in India, Sicily, Germany, France, Spain, England, Mexico, and the United States. The wide distribution of these spectroheliographs in longitude will permit the sun to be kept almost constantly under observation, so that the record of the state of the calcium flocculi will be sufficiently continuous for most purposes. The location of the Solar Observatory, because of its atmospheric advantages and its western longitude, and also because of its powerful instrumental equipment, should enable it to contribute in an important way to this international undertaking. The Observatory will also be able to assist in the observation of sun-spot spectra, and probably in other particulars.

The acceptance by the late Secretary Langley of an invitation to continue on Mount Wilson the work inaugurated by the Smithsonian Institution in the spring of 1905 has resulted most successfully. The cooperation we have thus been able to promote is proving advantageous to both the institutions concerned, especially on account of the close relationship between the Smithsonian studies of the solar constant and our own investigations of other solar phenomena. The investigations of Prof. E. F. Nichols on Mount Wilson, and the coming visit of Mr. John Evershed, lately appointed assistant director of the Kodiakanal Solar Observatory in India, afford other instances of work which the Solar Observatory hopes to continue and extend in the future. At this point I also wish to speak of the visit of Messrs. Smith and McGrath, of the United States Coast and Geodetic Survey, which is described more fully below. We are heartily indebted to Superintendent Tittmann and the gentlemen named for their cooperation in determining the astronomical latitude and longitude of the Solar Observatory.

STAFF.

At the opening of the year, Messrs. W. S. Adams and F. Ellerman were engaged in observational work with the Snow telescope. In February Dr. Henry G. Gale arrived from the University of Chicago, where he held the position of Instructor in Physics at the Ryerson Physical Laboratory. Dr. Gale was placed in charge of the work of our spectroscopic laboratory, in which he has recently been assisted by Dr. Charles M. Olmsted, who joined the Observatory staff, on temporary appointment, in August. Mr. Francis G. Pease has also assisted in some of the experimental work with the electric furnace in the Pasadena laboratory. Dr. H. K. Palmer, of the Lick Observatory, joined our staff in May, and has been engaged in bolographic investigations with the Snow telescope. He has also assisted Mr. Ellerman in the routine work with the spectroheliograph. On July 1 Mr. Adams left Mount Wilson to take charge of the computing division

in Pasadena. Miss Louise Ware was appointed a computer on July 1, and Miss Ruth E. Smith joined the computing division in August. Professor G. W. Ritchey has been in charge of all of the principal work of construction during the year.

Dr. E. F. Nichols, Professor of Experimental Physics in Columbia University, was engaged in special investigations on Mount Wilson during the summer.

The Smithsonian Expedition, which began its investigations on Mount Wilson in the spring of 1905, has continued its work this year, under the charge of Mr. Charles G. Abbot, Acting Director of the Smithsonian Astrophysical Observatory. Mr. Abbot has been assisted by Mr. Leonard R. Ingersoll, of the University of Wisconsin.

The astronomical latitude and longitude of the Solar Observatory were determined by Messrs. Edwin Smith and John E. McGrath, assistants of the United States Coast and Geodetic Survey, in December and January.

INVESTIGATIONS IN PROGRESS.

The program of investigations undertaken last year, with the instruments then available, has been continued and extended. It now comprises: (1) Daily photography of the sun with the photoheliograph; (2) daily photography of the sun with the spectroheliograph; (3) photography of the spectra of sun-spots; (4) photography of the spectra of the flocculi, for determination of radial velocity; (5) spectrographic investigations of the solar rotation; (6) bolographic investigations of the solar absorption; (7) certain special studies of stellar spectra, with a grating and prism spectrograph of high dispersion; (8) laboratory investigations; (9) studies of the correlation of solar and magnetic phenomena, made with the aid of a recording variometer.

The Snow telescope has continued to give excellent results, though the rapid deterioration of the mirror surfaces when constantly exposed to sunlight requires that they be resilvered very frequently. When the mirrors are even slightly tarnished, the change in focal length, during exposure to the sun, is rapid. For this reason they are kept covered except when the actual observations with the spectroheliograph, or with other instruments, are in progress, and between exposures a strong draft of air is blown upon them by electric fans. The use of an arc lamp, for setting the slit of the spectroheliograph on the H line, materially reduces the time of exposure of the mirrors to sunlight in this work. Experiments made in the Pasadena laboratory have shown that the form of a mirror, after distortion produced by heating the front surface with an electric heater, placed about a foot in front of the mirror, can be restored by heating the rear surface with a similar electric heater. The figure of the mirror when restored in this way is not perfect, but the advantages of the method have

seemed sufficient to warrant the construction of electric heating coils, which will be mounted behind the three mirrors of the Snow telescope. It is obvious that the manipulation of such a device will not be easy, and it has not seemed wise to attempt to use it during the fine summer weather, since the necessary experiments might affect seriously the routine observations. The difficulties which are experienced from changes of focal length do not interfere appreciably with work on spot spectra, the solar rotation, or bolographic investigations. Even in spectroheliographic work, which is much more exacting, the difficulty is reduced to a minimum by shortening the exposure time as much as possible.

The important results achieved by Dr. A. L. Day, in the manufacture of fused quartz, are reported by him elsewhere. It seems probable that if suitable graphite slabs can be obtained, the manufacture of fused quartz disks for telescope mirrors will become feasible. The question at present is whether sufficiently homogeneous graphite can be secured.

As it has been proven in our tests that the distortion of a mirror in sunlight is due to an actual bending of the disk, the front surfaee becoming convex and the rear surface concave, the idea of employing very thick mirrors has naturally suggested itself. Accordingly, the mirrors of the cœlostat to be constructed for the new "tower telescope," though only 16 inches in diameter, will be made of glass 12 inches thick. It is hoped that the resistance to bending of such thick disks will materially reduce the difficulty.

Our experiments with speculum metal have indicated, as suggested in the last annual report, that its distortion when exposed to sunlight is somewhat less than in the case of glass. However, the low coefficient of reflection of speculum metal is a serious objection to its use in an instrument like the Snow telescope.

Direct Photography of the Sun.

Daily photographs of the sun, on a scale of 6.7 inches to the diameter, are taken by Mr. Ellerman with the Snow telescope. These plates are used mainly for the purpose of comparison with spectroheliograph plates, in studies of the spots and faculæ. On account of the great pressure of work with the Snow telescope, it is hoped that the direct photographs may ultimately be made with another instrument, such as the tower telescope.

Work with the Spectroheliograph.

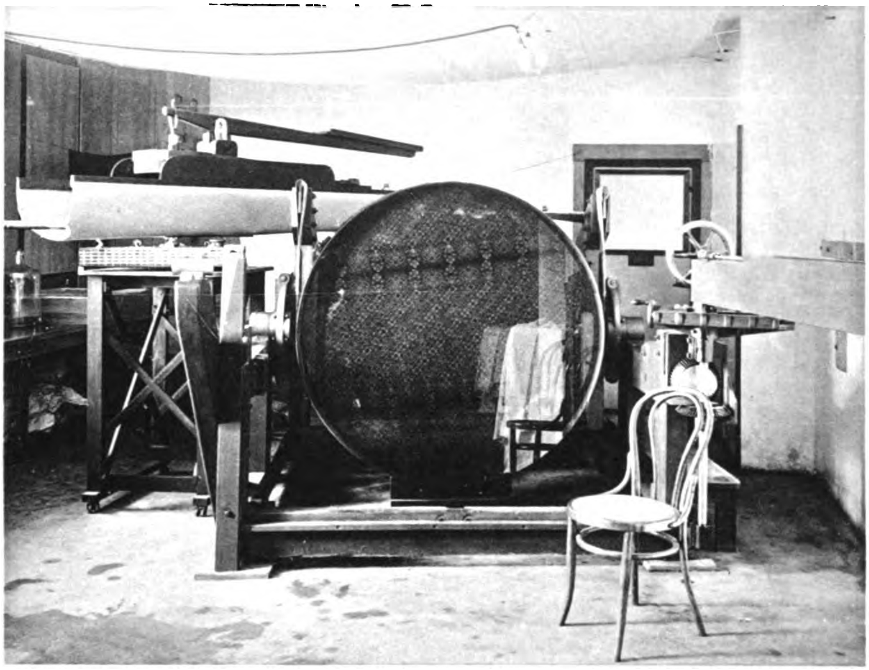
The 5-foot spectroheliograph, mentioned in the last annual report, was erected in the Snow telescope house in October, 1905. A general description of this instrument has been published in Contribution No. 7 of the Solar Observatory, and a more detailed account, with scale drawings, will

appear later. In all respects this instrument has proved thoroughly satisfactory, and reflects much credit on the work of our Pasadena instrument shop. The large aperture of the collimating and camera lenses gives perfect illumination at the limb of the sun, thus obviating a difficulty encountered in our previous work with the Rumford spectroheliograph.

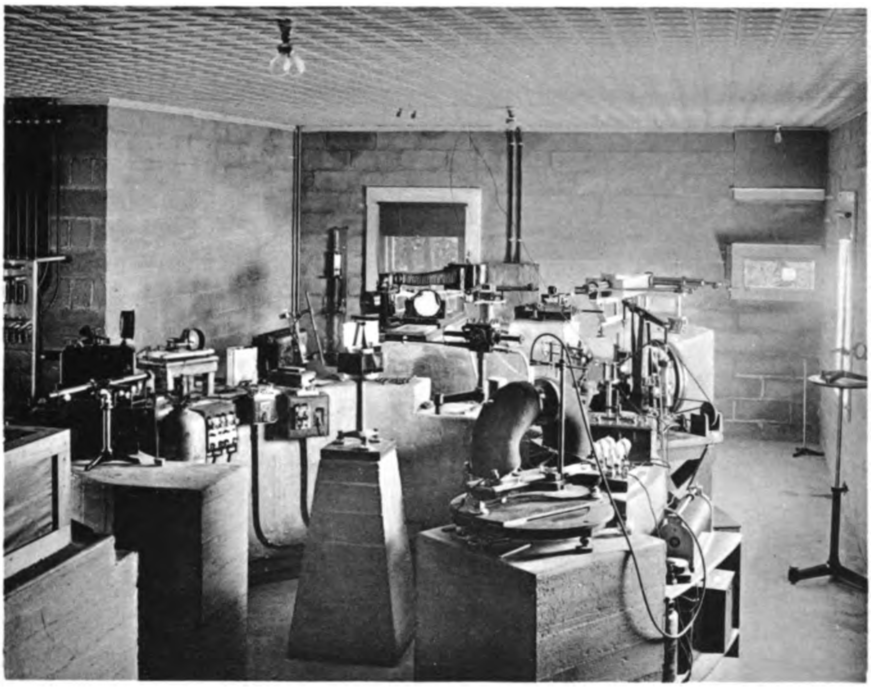
The driving mechanism, mercury flotation, methods of adjustment and of setting on the spectral lines, and all other features of the design have proved so satisfactory that no changes in the instrument have been required. After a series of experiments, with from one to four prisms, we finally decided to adopt two prisms for the daily work of the instrument, since it was found that they would give admirable results with the lines of calcium, hydrogen, and iron. The necessity of devoting this instrument to routine work, and the heavy demands placed upon it by the morning and afternoon program of observations, will prevent it from being used for experimental purposes. However, this necessity was foreseen; in fact, it was hardly supposed that the 5-foot spectroheliograph would serve so admirably for the routine work with hydrogen and iron lines.

A spectroheliograph of 8 inches aperture and 30 feet focal length was designed for experimental work on limited regions of the solar surface, with dark lines too narrow for use with the 5-foot spectroheliograph. The construction of this instrument has been indefinitely delayed, through the difficulty of making large prisms of sufficient homogeneity. Of three prisms ordered from the Carl Zeiss Company in February, 1905, only one has been delivered, and this proved entirely unsuitable. Indeed, it seems possible that sufficiently homogeneous glass can not be obtained for the purpose. For this reason an experiment was tried by Brashear in building up a prism of horizontal slabs of glass, carefully selected from telescope disks of the same melting and free, because of their small thickness (about one inch), from the difficulties of annealing encountered in large prisms. The resulting prism was much more successful than the single solid prism made by the Zeiss Company. Indeed, its resolving power was sufficient for the purposes of the spectroheliograph, but the amount of light scattered vertically, of no consequence in most classes of investigation, was sufficient to prevent it from meeting the extreme demands in this particular of the spectroheliographic work. It is accordingly being used, with excellent results, in our bolographic studies. I have now decided, in view of the difficulties encountered with solid glass prisms, to try some experiments with fluid prisms, in the hope that means will thus be found of completing the 30-foot spectroheliograph.

My studies of the spectroheliograph plates, other than those made with the globe-measuring machine (described in the work of the computing



60-INCH MIRROR TURNED DOWN FOR TESTING.



INTERIOR OF SPECTROSCOPIC LABORATORY.

division), have related especially to a comparison of hydrogen and calcium flocculi, and an examination of stereoscopic solar images. The Zeiss stereocomparator has proved of the greatest value in this work.

Stereoscopic comparisons of two calcium photographs, made at intervals of from one to ten hours, show the spherical surface of the sun in relief, and are likely to prove of considerable service in our future work. With the monocular micrometer of the stereocomparator, a comparison of hydrogen and calcium photographs of the same date has shown a relative displacement of the hydrogen flocculi towards the sun's limb, presumably due to their greater height above the photosphere. This result confirms my previous views, based upon other reasoning, as to the level of the hydrogen flocculi. A further confirmation of these views has been afforded by a study of the spectrum of the dark calcium flocculi, which are occasionally found at points on the solar surface occupied by unusually dark hydrogen flocculi. It had previously been assumed that these dark hydrogen flocculi were at a height above the photosphere corresponding to the dark H_3 and K_3 lines; in other words, in the upper and cooler region of the chromosphere. It is now found that the H_3 and K_3 lines are much strengthened and widened in these peculiar dark flocculi, and are also accompanied by a marked strengthening of the hydrogen lines. They are thus high-level phenomena and generally occur, in all probability, above the region of the bright H_2 and K_2 flocculi. Indeed, they sometimes appear, in the photographs, to overlie these bright flocculi. It is a noteworthy fact that most of these singular dark calcium flocculi are long and narrow in form; the meaning of this is not yet apparent.

I have devoted much time and attention to a consideration of the best methods of measuring and interpreting spectroheliograph plates, with results which will be published soon. The globe-measuring machine seems to satisfy all requirements for the determination of heliographic positions; for the comparison (when used as a stereocomparator) of photographs of the same and different dates; and for other related purposes. I am now engaged in perfecting a method of securing a measure of the solar activity in regions 10 degrees square upon the solar surface, as defined by the area and brightness of the calcium flocculi. It is obvious that some method of determining the solar activity of a given date, which shall be more satisfactory than that afforded by the total area of sun-spots, is greatly needed. The spots are so small that, even at times of maxima, the determination of their total area may involve a considerable percentage of error. Moreover, at sun-spot minima, they are sometimes absent from the disk for months together. The flocculi, however, are always present, in greater or lesser degree, upon the solar

surface, and their total area is so great that the percentage error in determining it should be less than in the case of sun-spots, in spite of the fact that their boundaries are less sharply defined. I believe, however, that the brightness of the flocculi, which varies greatly in different cases, should be taken into account, as well as their area. For this reason I have devised a photometric method of determining the total area and brightness of the flocculi, in regions 10 degrees square, and trust it will prove suitable for routine investigations.

Spectra of Sun-spots.

In my last annual report, reference was made to the fact that photographs showing widened lines in the spectra of sun-spots had been obtained, and that steps would be taken to interpret these phenomena through experiments in the laboratory. The investigation which has grown out of this work has been alluded to in the introduction to the present report. The photographs of the spectra of sun-spots, made by Mr. Adams and Mr. Ellerman, after the Littrow spectrograph of the Snow telescope had been given its permanent form, proved so satisfactory that they have served as the basis of our studies. It should be remembered that the principal phenomena of spot spectra comprise: (1) Fraunhofer lines of the same intensity as those of the solar spectrum; (2) lines that are widened or strengthened; (3) lines that are weakened or replaced by bright lines. The photographs successfully register not only the more conspicuous lines of these types, but also the multitude of fine lines into which the spot spectrum was visually resolved by Professor Young many years ago. In my photographic work on spot spectra at the Yerkes Observatory, which was done with the assistance of Mr. Ellerman, a few of the more conspicuous of these fine lines were recorded, but the scale of the spectrum was so small that their identity could not be determined with any certainty. The present photographs have a scale five times as great, with the result that thousands of the fine lines appear upon the plates, where their positions can be measured with precision. Measurements of these lines, by Mr. Adams, have shown that most of them are identical in position with the extremely faint lines recorded by Rowland in the solar spectrum. In other words, this feature of the spot spectrum is produced by a marked strengthening of the absorption of the solar atmosphere. However, the conclusion drawn by Dunér, from his visual observations, "that there is no fundamental difference between the general solar spectrum and that of the spots," is by no means warranted, for the intensities of the lines which are strengthened are not increased, in all cases, in the same proportion; on the contrary, the changes show the widest variations, some lines being unaffected, some enormously increased in intensity, and others greatly enfeebled.

The identification of the faint lines in the spot spectrum, although it cleared up the uncertainty as to their origin, by no means solved the problem regarding the cause of the characteristic spectral phenomena of spots. It seemed evident that extensive laboratory investigations might be needed for this purpose. The question was, however, to find some logical basis for a plan of attack. I have long been impressed with the following characteristic features of spot spectra: (1) The diverse behavior of different lines of the same element; (2) the fact that all of the strengthened lines lie in the visible spectrum, and that the most conspicuous of them are in the red, yellow, and green; and (3) the relatively great intensity in the less refrangible region of the general background of the spot spectrum. In considering these peculiarities, I could not fail to recall: (1) That in the spectra of the elements some lines increase in intensity, while others decrease, when the temperature falls; (2) that in spectra observed at low temperatures, the most prominent lines are likely to appear in the less refrangible region; and (3) that in a continuous spectrum (as well as in a spectrum of bright lines) a reduction in temperature involves a shift of the maximum toward the red. The similarity of these two groups of facts led to the belief that the most characteristic phenomena could in all probability be accounted for on the hypothesis that the temperature of the vapors within the spot is below that of the corresponding vapors within the sun's reversing layer. It was on this basis that the laboratory investigations, described on another page of this report, were undertaken.

The results so far obtained in our study of spot spectra, while strongly confirmatory of the hypothesis outlined above, of course constitute only the first steps in the extended researches required to test it in a complete manner. The use of an electric furnace, for the vaporization of metals in a carbon tube, where no electrical phenomena, other than those which result in the production of heat, can influence their radiation, is a most important element in the general investigation. This work, which is now in progress, will include all of the characteristic sun-spot metals that can be volatilized in the furnace. The solar side of the investigation will involve photographic and visual studies of spot spectra, carried on through a period of several years. Further stellar spectroscopic investigations must be delayed until the completion of the 60-inch reflector, as the Snow telescope is not well adapted for this phase of the work.

It must not be supposed that our hypothesis is intended to account for all of the phenomena of spot spectra. The bright lines occasionally observed are probably due to the overlying reversing layer, or to the chromosphere, especially in cases where eruptive action is concerned. The hypothesis will serve a useful purpose if it provides a basis for the

interpretation of the principal phenomena of strengthened and weakened lines, at the same time permitting an estimate of the approximate temperature of the vapors within the spot. Our work also appears to throw light on the much discussed question of the "enhanced" lines, favoring, as it does, the view that temperature alone is sufficient, in most cases, to account for these lines, though by no means precluding the view that high electrical potential, or sudden change of potential, may be capable of producing similar effects. Special attention will be given to these latter questions in our laboratory investigations.

Radial Motion of the Calcium Vapor in the Flocculi.

In connection with the study of the spectra of sun-spots, the work of Mr. Adams on the wave-length of the H and K lines in the flocculi, and the motion of the calcium vapor in the sun,* is of great importance. As the spectroheliograph so clearly shows, sun-spots are surrounded by extensive flocculi, consisting of cloudlike masses of calcium vapor, which sometimes overhang the smaller spots, so as to hide them completely. These calcium clouds rise from the faculæ, and they are presumably the effects of convection currents proceeding outward from the interior of the sun. It is evident that the radial motion of the vapor should be measurable from the displacements of the H_2 and K_2 lines, which correspond to the lower and intermediate regions of the chromosphere, and those of the H_3 and K_3 lines, which are produced by the absorption of the cooler vapor at a somewhat higher level. Mr. Adams's investigation began with a redetermination of the wave-lengths of the H and K lines in the electric arc, since the available determinations were not in sufficiently close agreement to promise the necessary accuracy. The large scale of the photographs, which were made with the Littrow spectrograph, permitted them to be measured with high precision, and the resulting wave-lengths of the H and K lines are probably very close to the truth. Using the arc lines as standards, Mr. Adams determined the wave-lengths of the H_2 and K_2 lines, and those of the H_3 and K_3 lines, at various points on the solar surface, and also (for the latter lines) over sun-spots. The average displacement of H_3 and K_3, which amounted to 0.006 tenth-meter toward the violet, corresponds to a velocity of approach of the calcium vapor amounting to 0.41 kilometer per second. The varying displacements obtained at different times, however, indicate that general conclusions should be based only on a very extensive investigation. The results given by the bright lines H_2 and K_2 also show a displacement toward the violet, so that it is probable that the calcium vapor in the flocculi may be regarded as moving upward. This would accord with the conclusions as to the nature of these objects based upon work with

* Contributions from the Solar Observatory, No. 6.

the spectroheliograph. As already stated, however, much more work along these lines must be undertaken, and special apparatus has accordingly been prepared for this purpose.

Spectrographic Investigations of the Solar Rotation.

The exceptional opportunity for a photographic investigation of the rotation of the sun afforded by the Snow telescope has been recognized from the outset, since the two essentials for securing results of the highest precision, namely, powerful spectroscopic apparatus and a large image of the sun, are both available. After some consideration it seemed desirable to employ an apparatus of the type first used by Langley for bringing the opposite edges of the sun side by side on the slit of the spectrograph, and in the spring of this year an attachment of this kind for the large Littrow spectrograph was completed.

A number of plates have been secured with this instrument, by Mr. Adams, and it has proved most satisfactory in its working. The excellent quality of the grating hitherto employed (the Kenwood 4-inch) has made it possible to use the fourth order of the spectrum, and so to obtain the benefit of great linear scale and resolving power without impairment of definition. Considerable attention has been given to methods for deriving heliocentric coordinates, and also to the question of the elimination of errors arising from change of focal length of the telescope during a series of exposures.

Preliminary measures made by Mr. Adams, on a few plates, indicate that the probable error for a single line is slightly less than that obtained by Halm for his series of visual observations. The possibility of combining the results for a considerable number of lines should, accordingly, result in a decided gain in the degree of accuracy. The measures so far made also suggest some interesting differences in the values given by the lines of different elements, but the work is as yet not sufficiently advanced to speak with certainty on this point.

Bolographic Investigations.

Bolographic observations with the Snow telescope were first made by Mr. C. G. Abbot in the summer of 1905. The pressure of the work in his observational program, however, prevented him from giving much time to these experiments, and I accordingly planned to continue them in connection with our solar investigations. We are indebted to Mr. Abbot, not only for much valuable advice as to the arrangement and use of the bolographic apparatus, but also for the loan of instruments without which the work could not have been undertaken this summer. The daily program of observations, which has been carried out by Mr. Palmer, has

comprised bolographic records of the radiation from various parts of the solar disk, together with special studies of the radiation of sun-spots and faculæ. In the work on the solar absorption, the prism is set so as to bring a given wave-length upon the bolometer strip, and the solar image is then allowed to move across the slit of the spectroscope, while the photographic plate upon which the galvanometer deflection is recorded is caused to move downward at a uniform rate. Since the height of the slit is only 3 mm., the record thus obtained is a measure, for all points along a solar diameter, of the radiation corresponding to the wave-length employed. On account of the well-known fact that the absorption of the solar atmosphere varies for different wave-lengths, the corresponding curves are of different forms. Their reduction, by a method previously employed by Mr. Abbot, gives a measure of the solar absorption. His previous investigations have led him to the belief that the solar absorption may show variations corresponding with the variations he has detected in the value of the solar constant. For this reason it will probably be advisable to continue routine observations of the character described, so that the results may be compared with his contemporaneous measures of the solar constant.

The constant temperature room in the Snow telescope house, previously used for the large stellar spectrograph employed for long exposures, has served admirably for the bolographic work. The triangular pier is large enough to carry all parts of the apparatus, for which it furnishes a most suitable support.

The bolographic studies of sun-spots made by Mr. Palmer, with the advice and cooperation of Mr. Abbot, have confirmed the result obtained by Mr. Abbot last year, namely, that the radiation of sun-spots falls off much more rapidly in the more refrangible region than does that of the photosphere. In other words, sun-spots emit a relatively large proportion of the less refrangible rays. It is extremely probable that this will serve to account, in whole or in part, for the fact that the total radiation of a sun-spot falls off less rapidly than that of the neighboring photosphere as the spot is carried toward the limb by the sun's rotation. It will be remembered that this phenomenon was the source of much discussion several years ago, and led many to the belief that sun-spots lie at a sufficient height above the photosphere to escape a considerable part of the general absorption. An explanation based upon the different quality of spot and photosphere radiation seems more plausible, and is capable of a rigorous test. It will only be necessary to employ monochromatic light in measurements of the comparative radiation of spot and photosphere at different distances from the limb. It is hoped that these experiments may be tried, with the aid of the Snow telescope,

within the near future. The work commenced on the radiation of the faculæ, which are found to give large deflections when near the sun's limb, will also be continued and extended.

Stellar Spectroscopy.

The investigations undertaken last year, in collaboration with Mr. Adams, with the object of ascertaining whether very high dispersion could be successfully used in photographing the spectra of bright stars, have been continued with satisfactory results. It has been found, as was hoped, that there should be no serious difficulty in photographing with the 60-inch reflector the spectra of several of the brightest stars on a scale equal to that employed by Rowland in his work on the solar spectrum. Such spectra, if obtained of the desired sharpness, should prove of the greatest service in our study of stellar evolution, since all of the principal stellar types, with a single exception, are represented among the bright stars which are likely to fall within the range of this investigation. The work with the Snow telescope has consisted mainly of a comparative study of the relative merits of gratings and prisms for this work, with the advantages decidedly in favor of prisms. It still remains uncertain whether prisms of sufficiently large dimensions, and of the necessary homogeneity, can be obtained, but we have hopes that the difficulties experienced in the case of our 30-foot spectroheliograph may ultimately be overcome.* The spectra of Arcturus, photographed with the gratings and prisms, have proved useful in a study of the sun-spot lines in the spectrum of this star, made by Mr. Adams.† The progress of our sun-spot investigations led to similar work on the spectrum of α Orionis, which showed that the lines which are about equally prominent in the spectra of sun-spots and in that of Arcturus are considerably more pronounced in the spectrum of α Orionis. This fact, together with other spectroscopic evidence obtained in an earlier investigation of red stars with the 40-inch Yerkes telescope, is strongly confirmatory of the view that the absorbing atmospheres of these stars are lower in temperature than that of the sun, leading to the inference that they are further advanced in their evolutional progress. A comparative study of stellar spectra, with special reference to the relative intensities of lines which vary with the temperature, will prove a matter of great interest. There is ground for the belief that the work in this field done by Sir Norman Lockyer and his associates, at South Kensington, can profitably be repeated and extended with such an instrument as the 60-inch reflector.

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* See page 68.

† Contributions from the Solar Observatory, No. 12.

Laboratory Investigations.

A brief description of the spectroscopic laboratory, constructed last summer on Mount Wilson, was given in the last annual report. A more complete account may be found in Contributions from the Solar Observatory, No. 10. The arrangement of the various light sources on an annular pier, in such a way that the image of any one of them can be brought upon the slit of the spectroscope, by setting a mirror at the center of the pier at the proper angle, has proved very convenient in practice. The study of spectra, which was begun by Mr. Gale immediately after he joined our staff last spring, has necessarily involved a comparison of a great number of light sources. As already explained, the hypothesis which served as a guide in our attempt to account for the strengthened lines and other phenomena of spot spectra assumes that their temperature is the principal variable concerned. As no electric furnace was then available, the work was begun with the aid of the ingenious form of synchronous arc used by Professor Crew, which permits the spectrum of a low voltage alternating discharge to be photographed at any desired phase from 0 to 90 degrees. The changes in the spectra recorded at decreasing phase angles correspond to those produced by decreasing temperatures, so that the device affords a simple means of testing the effect of temperature variations. The exposures corresponding to small phase angles are necessarily very long with this apparatus, and it therefore occurred to Mr. Gale that a reduction of the current in an ordinary carbon arc might accomplish the same purpose, and give brighter spectra. A comparison of the results given by a 30-ampere and a 2-ampere arc justified this view, and served as the most practical means at our disposal of producing a comparatively low temperature in the case of such metals as titanium and vanadium. The results obtained, and their bearing upon the spectra of sun-spots, have already been mentioned. The important fact was also discovered that those lines which are "enhanced" in the electric spark are very appreciably weakened in passing from the 30-ampere to the 2-ampere arc. The importance of this fact arises from the diverse opinions which have been expressed regarding the cause of the enhanced lines, and their production under different conditions. Special investigations of this subject have led many spectroscopists to believe that other variables may be quite as important as temperature in their effect upon the intensity of the enhanced lines. Crew, for example, has expressed the opinion that the essential cause of the production of enhanced lines in arc spectra is a rapidly changing electromotive force. Hartmann, on the other hand, in his work on the arc in water, ascribed enhanced lines observed under these conditions to the effect of hydrogen gas produced by the decomposition of the water. It accord-

ingly became of great interest to determine whether the observed changes in spectra could be accounted for by variations in temperature alone, as distinguished from the direct effect of any electrical or other conditions. Mr. Gale found the results of the work with the short arc to be entirely confirmed, in a comparison of the cooler flame of the arc with the core. Since that time all doubt has been set at rest, as regards the sufficiency of an hypothesis based upon change of temperature, by experiments made within an electric furnace, where the vapors are inclosed in a carbon tube, the outer walls of which are heated by an electric arc. In the case of iron, for example, the same lines that are strengthened in the synchronous arc at low phase, in the 2-ampere arc, and in the flame, are strengthened in the electric furnace under low temperature conditions. This fact, of course, does not preclude the possibility that other causes, such as rapidly changing electromotive force, may operate in the sun and stars, but it surely affords a firm basis for an hypothesis which regards temperature as the most important variable.

Relationship Between Solar and Magnetic Phenomena.

The investigations described above relate, for the most part, to the study of the sun as a typical star. Of equal importance, however, is the conception of the sun as the central body of the solar system, with special reference to its effect upon terrestrial phenomena. The possible variation of the intensity of the solar radiation, and its influence upon climate, is the work to which the Smithsonian Institution is devoting its attention. The measurement of the absorption of the sun's atmosphere, as related to any such variations of the solar radiation, is also receiving attention in our bolographic work with the Snow telescope. The variation in the solar activity, as recorded on the spectroheliograph plates, may also prove to have an important bearing on this question of the solar radiation. There stills remains to be considered the relationship of the solar activity to terrestrial magnetism. In this department of our work we are fortunate in having the cooperation of Dr. L. A. Bauer, Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

In previous studies of the relationship between solar and magnetic phenomena, the total area of the sun-spots has been taken as the index of the solar activity. As already remarked, however, this total area may not prove to be the most satisfactory index, in view of the comparatively small size of the spot images and their absence from the disk during long periods near the time of minimum. It seems probable that the photographs of the calcium flocculi will furnish admirable data for the purposes of this research, because of the great total area of the flocculi, the fact that they are never altogether absent from the disk, and the

facilities such photographs offer for detecting eruptive phenomena. Accordingly, our studies of the total area and brightness of the flocculi are being made with special reference to their comparison with the records of magnetic phenomena.

In order to have at hand a means of at once detecting magnetic storms, a special instrument, devised for this purpose, has been installed on Mount Wilson, with the kind advice and cooperation of Dr. Bauer. This recording variometer gives a continuous record of the magnetic variations; it is also provided with an alarm, which notifies us in case the deflections become at all marked. We are thus enabled to take special photographs of the sun at times when the disturbed state of the earth's magnetism might lead to the supposition that active solar phenomena could perhaps be detected with the spectroheliograph. The variometer has been in regular use, in the charge of Mr. Ellerman, since last spring. It promises to be a most effective part of our equipment.

SPECIAL INVESTIGATIONS.

Two special investigations were carried on by Professor Nichols during the summer. The first of these was a study of the effect of the ionization produced by X-rays on the absorption or radiation of a gas or vapor. NO_2, for example, absorbs X-rays strongly. When a continuous source is observed through this gas, a very characteristic absorption spectrum is produced. The question was to determine whether the degree of the absorption, or its character, is in any wise altered when X-rays are sent through the gas. The effect was studied both visually and photographically. If any change takes place, it is small and can only be determined from a more complete study of the photographs than Professor Nichols has yet had an opportunity to make. This, and other related investigations, will be continued by him, in the hope that light will be thrown on the nature of the radiation processes that obtain in solar prominences and in other celestial phenomena.

The second investigation dealt with the question whether the "Reststrahlen," obtained after repeated reflections from rock-salt surfaces, reach us in any appreciable amount from the sun. By the aid of repeated reflections on rock-salt surfaces, the rays of other wave-length were eliminated from the sunlight, which was then focused upon the vane of a very sensitive radiometer. The purity of the observed beam was tested by transmission through a rock-salt screen, and by comparative tests of the light of an electric arc. The very small deflections observed indicate that if any light of this wave-length reaches us from the sun, its intensity is inconsiderable. The exact quantitative results, however, can not be given until the reductions now in progress are completed.

LATITUDE AND LONGITUDE OF THE SOLAR OBSERVATORY.

The results obtained by Messrs. Smith and McGrath, of the Coast Survey, for the astronomical latitude and longitude of the Solar Observatory, may be found in Contribution No. 9. They may be briefly summarized as follows:

The latitude observations, which were made on three nights, gave a weighted mean value of $34^\circ\ 12'\ 55.07'' + 0.06''$. The reduction to sea level, to take account of the curvature to the vertical, is $0.28''$, giving $34^\circ\ 12'\ 54.79''$ as the reduced latitude of the point of observation.

The difference of longitude between Los Angeles and Mount Wilson was determined, with the aid of the new transit micrometer, on six nights. The mean difference is $+0^m\ 47.571^s + 0.008^s$. From the known longitude of the transit at Los Angeles, determined from the observations of 1892, the longitude of the transit at Mount Wilson comes out $7^h\ 52^m\ 14.130^s = 118^\circ\ 3'\ 31.95''$. Mr. Smith determined by local triangulation the position of the Snow telescope pier, with reference to his observing station, and thus obtained the following results:

	°	′	″
Mount Wilson triangulation station:			
Latitude	34	12	59.72
Longitude	118	3	45.54
Snow telescope pier:			
Latitude	34	12	59.53
Longitude	118	3	34.89

These values, as compared with the geodetic position of the Mount Wilson triangulation station on the United States standard datum, show that the astronomical latitude is $26.50''$ less than the geodetic, and the astronomical longitude is $5.63''$ greater than the geodetic. The deflection in the meridian is thus one of the largest yet observed in the United States.

SMITHSONIAN EXPEDITION.

The large number of determinations of the solar constant made by the Smithsonian Expedition during the summers of 1905 and 1906 should be sufficient to settle beyond any doubt the important question whether this quantity is actually a constant, or undergoes such variations as the previous work in Washington led Secretary Langley and Mr. Abbot to suspect. The summer weather in Washington is usually unfavorable for work of this kind, but the spring and autumn furnish a greater number of opportunities for simultaneous observations. The very close agreement of the measures made on the same date at the two stations indicates that the method of correcting for absorption in the earth's atmosphere is thoroughly sound. I heartily agree with Mr. Abbot's view that the most

effective means of continuing this work would be through the establishment of a mountain station in the southern hemisphere. In this way a continuous series of observations could be carried through that part of the year which corresponds to our rainy season. The joint work of three stations—one at Washington, one at Mount Wilson, and one in the southern hemisphere—would undoubtedly permit the solution of the most important problem involved in the comparative study of solar and terrestrial phenomena.

In undertaking cooperative observations on the solar constant, the International Union for Cooperation in Solar Research will doubtless devote special attention to the methods which Mr. Abbot is employing. It would seem essential, if pyrheliometric observations are to be freed from the effects of atmospheric absorption, that the bolographic method, or some analogous plan, should be adopted. The new forms of pyrheliometer which Mr. Abbot has devised and tested should also receive most careful consideration by all who are interested in this field of research.

COMPUTING DIVISION.

Much attention has been devoted to the question of the best organization of the computing division. While there would be certain advantages in having photographs measured and reduced on Mount Wilson, the disadvantage of quartering a large force of computers there seems to outweigh them. With the completion of the Mount Wilson road and the rapid means of communication thus afforded, there should be no practical difficulty in carrying on this work at our Pasadena offices. This agrees with the general principle, adopted at the outset, that the work on Mount Wilson should be confined, so far as possible, to observations.

Accordingly, our Pasadena building was enlarged last spring by a brick addition, adjoining on the east side the long hall used for optical testing purposes. The addition is divided into a series of rooms, including a library, an office for the superintendent of the computing division, Mr. Adams, and six small rooms, each serving as an office for one computer. Cases for the storage of photographs are placed in the hall into which the offices open. The optical testing hall, which is entered by a door from the computing quarters, serves admirably for the globe-measuring machine, or "heliomicrometer," which is installed there. The use of the hall for this purpose, and also for the Littrow spectrograph of 18 feet focal length, and the transformer and electric furnace employed with it, does not interfere in the least with its employment for testing mirrors of great focal length.

The equipment of the computing division now includes a Toepfer measuring machine, capable of measuring spectra 6 inches long; a Gaertner measuring machine, for spectra 18 inches long, or for the meas-

urement of rectangular or polar coordinates on 10 by 12 plates; a small Gaertner machine for stellar spectra; the heliomicrometer; a Hartmann microphotometer by Toepfer; a special instrument for measuring the area and intensity of the flocculi; and two calculating machines. On Mount Wilson there is also a Zeiss stereocomparator, with monocular micrometer attachment, and a small measuring machine.

Reference has already been made (p. 69) to various methods which have been employed in the measurement and discussion of spectroheliograph plates. In the study of the solar rotation, as indicated by the motion in longitude of the flocculi, the important requirement is a means of measuring heliographic positions. Photographs taken at intervals ranging from ten hours to two or three days are compared with the stereocomparator, and those points in the flocculi which show the smallest changes in form are marked for measurement on the successive plates. The method for obtaining heliographic positions at present in use at Greenwich and elsewhere involves the measurement of the polar coordinates of the points in question, followed by a computation which necessarily occupies considerable time. In routine work requiring the measurement of from 50 to 75 points on each one of several thousand plates, the employment of some method which would eliminate all computations is evidently most desirable. The globe-measuring machine, recently named the "heliomicrometer," was accordingly devised for this purpose. The form of this machine, briefly described and figured in the last annual report, required the use of two 4-inch telescopes, each of 60 inches focal length. One of these telescopes was directed toward the photograph of the sun, placed at a distance of 60 feet. The other was directed toward a globe, at approximately the same distance. By means of suitable reflectors the images of the globe and plate given by the two telescopes were united in a single eyepiece. The flocculi were then seen upon the surface of the globe, which was ruled with meridians and parallels one degree apart. By setting the axis of the globe parallel to the axis of the sun for the date of the photograph, the heliographic latitude and longitude of any point on the photograph could be read off directly, by estimating its position with reference to the neighboring meridians and parallels.

A measuring machine of this form was constructed in our Pasadena instrument shop. In experimenting with it, it occurred to me that it would be far better if a cross-hair were set on the point to be measured, before the image of the globe had been thrown into the field of view. In this way settings could be made on the most delicate details of the photograph, which would be lost to view when observed in projection on the illuminated surface of the globe. The method still involved, however, the undesirable element of estimating the position of the cross-hairs with

respect to the rulings on the globe. In order to render the method of the highest precision, it was evident that the substitution of divided circles for the ruled surface of the globe should prove most advantageous. The adoption of this conclusion led to the reconstruction of the machine. In its present form, the two telescopes of the heliomicrometer are mounted immediately above the globe and photographic plate. Two plane mirrors, placed at a distance of 30 feet, receive light from the plate and from the illuminated surface of the globe, and reflect it to the two telescopes. All motions of adjustment, for centering the plate on the globe, setting the cross-hairs on the object to be measured, rotating the globe, etc., can be effected by the observer from his seat at the eye-end of the telescope. In the operation of measurement, the cross-hairs are first set on the flocculus and the globe is then illuminated. The surface of this globe is not ruled with meridians and parallels, but simply bears a small circular dot at the intersection of the equator and the central meridian. By rotating the globe in longitude and in latitude, this dot is made to coincide with the intersection of the cross-hairs. It is then only necessary to read off, on circles provided for the purpose, the latitude of the flocculus and its difference in longitude from the center of the sun. It has been found by comparative tests that the operation of measurement with the heliomicrometer requires no more time than with an ordinary measuring machine giving polar coordinates. The resulting precision is equally great, and all computations are avoided. The heliomicrometer is easily transformed into a type of stereocomparator, for comparing two plates, by mounting a second photograph of the sun in front of the globe, and illuminating it from behind. In this way the flocculi on successive plates are selected for measurement and marked by means of an electric pen, controlled from the eye-end of the telescope. The instrument also has other useful applications in connection with the reduction of solar photographs.

Three computers are now employed under the direction of Mr. Adams. The routine work comprises:

(1) Measurements of heliographic positions of flocculi with the heliomicrometer, for the determination of the solar rotation and other purposes.

(2) Measurements of the area and brightness of the flocculi in regions 10 degrees square on the solar surface, for the determination of the solar activity and its variation with the sun-spot period.

(3) Studies of the lines affected in photographs of the spectra of sunspots.

(4) Studies of the changes in relative intensity of lines in spectra obtained at high and low temperatures.

The study of laboratory photographs, referred to in paragraph 4, has been done for the most part by Mr. Adams. He has also given much attention to the study of the sun-spot lines and the measurement of photographs taken in connection with his spectrographic investigation of the solar rotation.

CONSTRUCTION DIVISION.

The work of the construction division, under the superintendence of Mr. Ritchey, has been confined, for the most part, to the design and building of instruments and the work of widening the New Trail. A very large amount of work has been accomplished, however, and the completion of the Mount Wilson road will permit the resumption of building construction on Mount Wilson in the spring of 1907. The heavy expense of transportation over the present trail has made it seem advisable to postpone such work until the new road becomes available.

60-Inch Reflector.

The work of polishing and figuring the 60-inch mirror, which was undertaken in the autumn of 1905, has progressed almost to completion. As the greatest precautions were necessary in order to avoid danger from scratches, changes of figure due to temperature variation, etc., much time was devoted at the outset to the perfection of the machinery and appliances of the optical shop. The room in which the large grinding machine stands is provided with double windows, sealed so as to prevent the admission of dust. On account of the considerable fall of temperature at night during the cooler months, an automatic heater was installed for the purpose of maintaining the air in the room at practically constant temperature. The air is filtered before it enters the room, the walls and ceiling are shellacked, canvas is suspended above the grinding machine, the floor is kept wet during the polishing, and various other precautions are taken to reduce the danger of scratches. They have proved most successful, and the perfect polish of the glass surface leaves nothing to be desired. An important development of the year has been the perfection of a method of parabolizing, by Mr. Ritchey, which completely eliminates the necessity of any hand work. Thanks to this method, the parabolizing has already been pushed so far that the completion of the work will require but a short time.

In order to obtain a thoroughly satisfactory test of the figure, Mr. Ritchey decided to make a plane and a concave mirror, each 36 inches in diameter. By means of the parallel rays obtained with the aid of such a plane mirror, the final tests of the paraboloid will be made. A grinding machine for this work was built during the year, and the two mirrors are already well advanced. The convex mirrors for the 60-inch

reflector are being made with the 24-inch grinding machine. The plane mirrors must be given an elliptical form, and a special machine for grinding their edges in this form has been designed and constructed.

Other work of the optical shop has included the completion of a mirror of 24 inches aperture and 143 feet focal length for the Snow telescope, and a 20-inch plane mirror for testing purposes. Small plane mirrors for the heliomicrometer, and concave mirrors for use in the laboratory, have also been made.

Except for the delay occasioned by the San Francisco earthquake, the progress of the work on the mounting for the 60-inch reflector has been very satisfactory. An erecting house, 70 by 20 feet, and 25 feet high, was constructed in the spring on our grounds in Pasadena. In this was installed an electric traveling crane, capable of carrying loads of 15 tons. This crane has proved most efficient in operation, permitting the heavy parts of the mounting to be handled with the greatest ease.

The mounting, as constructed by the Union Iron Works Company, and delivered at our shop early in September, comprises the following parts:

Triangular base, 15 feet long and 9 feet wide at the widest part. This is divided longitudinally into two parts, each of them weighing 3½ tons.
Upper bearing, or column, for polar axis, weighing about 4¾ tons.
Lower bearing for polar axis.
Hollow nickel steel polar axis, 15 feet long, weighing 4½ tons.
Hollow steel float, 10 feet in diameter, weighing 4 tons.
Mercury trough, bolted to upper bearing and carrying the mercury in which the moving parts of the telescope are floated.
Cast-iron fork, weighing 5 tons, to be bolted to upper end of polar axis.
Worm-gear, 10 feet in diameter, weighing nearly 2 tons. The teeth of this worm-gear will be cut by our own machinists.
Bevel-gear, 7½ feet in diameter, weighing 1¼ tons, fitting with the worm-gear on the polar axis, and connected with electric motor for quick motion in right ascension.

The skeleton steel tube of the telescope is not yet completed by the Union Iron Works Company. The work on the instrument to be done in our own shop comprises the cutting of the worm-gear; the construction and fitting of the driving-clock (now nearly completed); the attachment of electric motors for quick and slow motions; the construction of a support system for the 60-inch mirror; supports for the small mirrors, etc. The entire instrument will be completed and tested by actual observations in Pasadena before it is taken to Mount Wilson.

The electric truck, on which the parts of the mounting are to be carried over the Mount Wilson road, is nearing completion at the shops of the Couple-Gear Freight-Wheel Company in Grand Rapids, Michigan. This truck, which was specially designed for the present work, will be capable of carrying loads of 5 tons. It is fitted with steering gear at both ends, and in other respects is adapted for the difficult work of transportation over a steep and narrow road.

PASADENA OFFICE AND ERECTING BUILDING.

LOWER PART OF COMPLETED ROAD.

Other Construction.

Apart from the large amount of work done on the 60-inch mounting, and the construction of the grinding and polishing machines for the optical shop, the instrument shop has accomplished a great deal during the year. The globe-measuring machine, after construction in its original form, was completely remodeled, as already described. A large circular dividing engine was also built and provided with a 36-inch circle by Warner & Swasey, which is guaranteed to have no error greater than 2 seconds of arc. This engine will be used for dividing the fine circles of the 60-inch reflector. It has already been of service in dividing the circles of the heliomicrometer, and for other purposes. The completion of the 5-foot spectroheliograph, and of the 18-foot Littrow spectrograph, used with the Snow telescope, should also be mentioned. Electric heating apparatus has also been made for the mirrors of the Snow telescope, and a large amount of special apparatus for the spectroscopic laboratory on Mount Wilson. The erecting house for the mounting of the 60-inch reflector; the wooden frame of the electric crane; and the carpentry in the rooms of the computing division, including the shelves and tables, were the work of our men. A very large number of patterns have been made in the pattern shop.

The small amount of construction done by our workmen on Mount Wilson includes the addition of a wing to the Monastery and the erection of a concrete storehouse, adjoining the spectroscopic laboratory. A large amount of brush was cut on the mountain as a further safeguard against forest fires.

Mount Wilson Road.

Through the kind cooperation of Director D. T. MacDougal, of the Department of Botanical Research, it has been possible to entrust the superintendence of the important work of widening the new trail to Mr. Godfrey Sykes, who is acting under the general direction and with the active cooperation of Mr. Ritchey. At present about 120 men are employed, working in three gangs. Every effort is being made to hasten the work, so as to avoid the delays and serious expense which might result if it were greatly prolonged after the opening of the rainy season. It now appears probable that the only work which will remain uncompleted at that time will be the rock-blasting on the sides of Mount Harvard. It is hoped that the repairs to the road that will undoubtedly be necessitated by the winter rains can be completed within a short time in the early spring, so that the heavy program of construction on Mount Wilson planned for the summer of 1907 can be carried out.

100-INCH REFLECTOR.

In Contribution No. 13 I have outlined the difficulties that must be overcome in the construction and use of a 100-inch mirror. These include:

(1) The manufacture of a suitable glass disk. In view of their long experience and full understanding of the requirements, it seems probable that the St. Gobain Company will be able to make a satisfactory disk, although the amount of glass to be cast in a single piece will weigh over 4½ tons.

(2) The production of a perfect paraboloidal figure. After his successful work with the 60-inch reflector, Mr. Ritchey will undoubtedly be able to accomplish this difficult task.

(3) The design and construction of a mounting capable of carrying the mirror with the necessary accuracy. There seems no reason to doubt that the experience gained from the use of the 60-inch reflector will render it possible to design a satisfactory mounting which the Union Iron Works Company will be able to construct in such a way as to meet all requirements.

(4) Serious changes of focal length, due to variations in the temperature of the mirrors. The fact that the night temperature on Mount Wilson is nearly constant after 9 p. m., during the best observing season, and the possibility of maintaining the mirrors during the day at the average night temperature by means of a refrigerating plant, seem to indicate that no insuperable difficulties will arise from this cause.

(5) Imperfect seeing. Our tests of the definition at night on Mount Wilson, made with the Snow telescope and smaller instruments, lead us to believe that the occasions on which the full aperture of the mirror can be used for the most exacting photographic work will not be very infrequent. The average conditions will undoubtedly permit the 100-inch reflector to be used advantageously in the various classes of work in which large light-gathering power, rather than the most perfect definition, is essential.

Campbell, W. W., Lick Observatory, Mount Hamilton, California. Grants Nos. 231 and 342. (*a*) *Pay of assistants to take part in researches at the Lick Observatory and* (*b*) *measurement and reduction of photographic plates of Eros.* (For previous reports see Year Book No. 2, p. xix; Year Book No. 3, p. 86, and Year Book No. 4, pp. 82–83.) **$7,000.**

Report.—(*a*) In the spectrographic determination of stellar velocities there have been employed, as Carnegie Institution assistants, in the past year:

Dr. Joseph H. Moore, October 1, 1905, to July 1, 1906.
Mr. Keivin Burns, October 1, 1905, to October 1, 1906.
Dr. B. L. Newkirk, September 1, 1906, to October 1, 1906.

During ten months of work Dr. Moore secured 185 spectrograms with the Mills spectrograph attached to the 36-inch refractor, made first measure-

ments and reductions of 156 spectrograms, made definite measures and reductions of 40 spectrograms, and prepared seven short papers for publication.

Mr. Burns secured 43 spectrograms with the Mills spectrograph, made first measures and reductions of 100 spectrograms, and definitive measures and reductions of 313 spectrograms. He also completed an extensive study of the orbit of the spectroscopic binary λ Andromedæ, and his manuscript is now in the printer's hands.

The one month of Dr. Newkirk's service has been devoted to the measurement of planetary, lunar, and standard-star plates in order to train his judgment in selecting suitable lines and to acquire fairly constant habits of measurement.

Experience has demonstrated that this preliminary training can not be neglected. In measuring ordinary and isolated stellar images we have a simple problem in comparison with that of measuring spectral absorption lines whose appearances differ for the various lines in the same star and for the same lines in different stars. There is an embarrassing scarcity of well-trained men and women available for service in this work. At no time has it been possible to secure as many assistants as desired. Good progress has been made, but relatively to the needs of the case it should be more rapid.

Mr. R. F. Sanford has been engaged since June 18, 1906, as assistant to Professor Tucker in meridian-circle work. He has taken part in computations upon observations of a long list of latitude stars made for the use of Prof. C. L. Doolittle, and after acquiring consistent habits of measurement is assisting Professor Tucker in observing his carefully prepared program of stars by fundamental methods.

(*b*) A grant of $3,000, made in December, 1904, was available for the measurement and reduction of Eros photographs, secured by Dr. Perrine with the Crossley reflector, for the purpose of improving our knowledge of the sun's distance from the earth. Miss Fredrica Chase, formerly of Vassar College, and Miss A. M. Hobe, formerly of the Students' Observatory, University of California, have been engaged on this work since December 1, 1905, under the supervision of Dr. Perrine. Five hundred and twenty-five photographs have been selected as suitable for the investigation. Of these, 487 have been measured definitively, and 38 remain to be measured as soon as the comparison stars for them shall have been selected. Half the work of taking differences, forming means, and checking for the plates measured has been done. Extensive auxiliary tables to facilitate the final reductions have been completed and are ready for use. The progress made has been more rapid than was anticipated. The methods employed in this investigation are designed primarily for a differential determination of the sun's distance, based upon the Mount Hamilton observations alone; but secondarily, the measures obtained will be available for combining the Crossley observations with those made at other stations. Mr. A. R. Hinks, chief assistant

in the University Observatory, Cambridge, England, is planning to combine them with the Cambridge observations. With that purpose in view, he is supplying the lists of comparison stars, and is deducing their accurate positions.

Newcomb, Simon, Washington, District of Columbia. Grant No. 233. *Investigation of the mean motion of the moon from observations from the earliest historic times to the present*, $2,500. Grant No. 321. *To aid investigations in mathematical astronomy, statistical methods, and economic science*, $5,000. (For previous reports see Year Book No. 2, p. xxi; Year Book No. 3, p. 90, and Year Book No. 4, pp. 83–84). $7,500.

Professor Newcomb submits the following list of researches which he has carried on with the aid of the above grants:

Discussion of the Mean Motion and other Elements of the Moon from Eclipses and Occultations from the Earliest Babylonian Records to the Present Time.—So far as can be determined at the moment, the computations for this work, bringing it up to the end of 1904, are completed. The last stage, that of the final discussion, will be entered upon as soon as practicable.

Investigation of the Action of the Planets on the Moon.—This work was undertaken as a necessary adjunct of the preceding one, because definite conclusions from observations can not be drawn until the question of the action of the planets on the moon is settled. As the work was pursued, its ramifications became vastly more intricate than was anticipated, and the method of pursuing it had to be frequently amended and improved. The number of inequalities in the longitude which it is desirable to take account of was found to be nearly 200. It was only in September that the work could be brought into final shape, and it is now in the hands of the printer.

Discussions of Observations of the Satellite of Neptune with a Determination of the Mass of that Planet.—This work was commenced several years ago with the aid of a grant from Miss Bruce. Not being urgent, it is only now approaching completion. Its most important purpose is to determine whether the motions of the planet Uranus indicate the action of any unknown body.

Investigation of Terrestrial Temperatures to Determine whether they are Affected by Variations in the Sun's Radiation of Energy.—This work, like some others, has proved much more laborious than was anticipated. The heavy computations are, however, believed to be complete, and it only awaits the final discussion of results. This I hope to enter upon at an early date.

Besides these four works preparations have been made for another considerable one, the construction of new tables of Mars. This work will require several years for its completion, and will not be seriously undertaken until the four works above mentioned are finished.

The Compendium of Spherical Astronomy mentioned in the last report was published by the Messrs. Macmillan in May.

Russell, Henry N., Princeton, New Jersey. Grant No. 207. *Photographic determinations of stellar parallaxes.* (For previous report see Year Book No. 3, pp. 92-93.) $1,000.

Abstract of Report.—Dr. Russell's work was interrupted by illness in the autumn of 1904, and this and its attendant effects with other unavoidable delays prevented him from continuing his work until the spring of 1906. His researches are now in active progress, however, and the present state of the work is as follows:

The color-screen (consisting of a patch of colored gelatin film upon a plane-glass plate), which was used in photographing bright stars, became useless in the spring of 1905, owing to the contraction of the gelatin, which tore it loose from the glass. This unavoidable accident put an end to the observations of 25 stars, as photographs taken with a new screen would not be strictly comparable with the old ones. Of these stars, 5 had been observed at three parallactic epochs, so that their parallaxes can be deduced in the ordinary way. The photographs of 10 more, which were observed at two epochs only, can be used to give approximate values of their parallax. The remaining 10 stars, observed at one epoch only, are lost to the present work. It may also be necessary to reject one or two others, for which observations at the critical dates were prevented by persistent bad weather.

Excluding these stars, the total number of available plates obtained up to the date of this report is 252, of 40 different fields. Of these, 226 have either been measured by the writer or are now available for measurement. The remaining 26 have been taken at Cambridge during the past winter by the great kindness of Mr. A. R. Hinks, chief assistant at the Cambridge Observatory, England, and will be forwarded to the writer after some 8 more plates, which are still needed for the full completion of the work, have been obtained; 122 of these plates, belonging to 32 series, have been measured, and all these have been completely reduced. Under the present circumstances it is hoped that the larger part of the remaining plates may be measured during the present academic year.

Six series (for the stars Lalande 21185, γ Virginis, Lalande 25372, Berlin B 5072 and 5073, o Ceti, and β Cassiopeiæ) have been completed, and least-square solutions made for the parallax. The results are in general highly satisfactory, and show the photographic method to be one of the highest accuracy.

The results for the first two stars were published in the Monthly Notices of the Royal Astronomical Society for June, 1905. At the same time a brief account of the methods used in the stellar parallax researches at Cambridge was published jointly by Mr. Hinks and the writer.

This work, interrupted by many vicissitudes, has now, through the liberality of the observatories at Cambridge and Princeton, every prospect of completion in as satisfactory manner as if no interruptions had occurred.

BIBLIOGRAPHY.

Eames, Wilberforce, Lenox Library, New York, N. Y. Grant No. 343. *Completion of Sabin's "Dictionary of Books Relating to America," from Smith (Henry H.) to Z.* $3,600.

The research work required to prepare the proof for the printer was begun on June 15, 1906, by Leonhard Felix Fuld, under the immediate administrative supervision of the grantee. The research work is being carried on in the Lenox Library, Astor Library, Library of the New York Historical Society, and Library of Columbia University in New York City, and every endeavor is made to locate and personally inspect a copy of each book entered in the Dictionary in one of these libraries. If no copy can be located in New York City, recourse is had to correspondence with the Boston Public Library, the Library of Harvard University, the Library of the Boston Athenæum, the Library of the American Antiquarian Society at Worcester, Mass., the Library of Congress, and other libraries whose collections are particularly rich in Americana. No title is included in the Dictionary unless a copy has been located in some library, and such library is indicated by an appropriate initial in the entry or unless the title is one which though obtained from a reliable bibliographical authority can not be located in any library, in which case the bibliography from which it is taken will be mentioned in a note. The original plan of Sabin's Dictionary is being followed in all material respects.

Weeks, F. B. (under direction of Dr. G. F. Becker), U. S. Geological Survey, Washington, D. C. *Bibliography of geophysics.* Grant No. 336. (For previous reports see Year Book No. 3, p. 81, and Year Book No. 4, p. 86.) $1,000.

Mr. Weeks reports that during the year 3,104 volumes have been examined, and 11,737 author cards and 6,094 index cards have been written.

Adding to the above the work previously completed gives—

Total number of volumes examined to date	4,090
Total number of author cards written	18,797
Total number of index cards written	7,871

The work of typewriting the cards necessarily has been somewhat behind that of the examination of the literature. About 1,000 author cards are yet to be written, and approximately one-third of the index cards have been written. Below is tabulated the material by languages:

Volumes in English	1,586
Volumes in French	635
Volumes in German	1,381
Volumes in Scandinavian and Dutch	434
Miscellaneous	54
Total	4,090

Future Work.—The greater part of the Italian and Spanish literature is yet to be examined. It is thought not desirable to include papers printed only in Russian, Polish, Hungarian, and Japanese languages, as few persons could make use of this material. To properly treat it would require the title of each paper in the original language and a translation into English, French, or German, which would add greatly to the amount of printed matter and to the cost of the work. Abstracts of such papers printed in one of the commonly used languages will be included. A considerable amount of English literature also remains to be examined.

It is believed that the publication of this work will make 3,000 double-column pages, making four volumes of approximately 750 pages each.

Fletcher, Robert, Army Medical Museum, Washington, District of Columbia. Grant No. 322. *Preparation and publication of the Index Medicus.* (For previous reports see Year Book No. 2, p. 23; Year Book No. 3, p. 95, and Year Book No. 4, p. 85.) $10,000.

The Index Medicus for 1905 was duly completed after the publication of the report in the last Year Book. It formed a volume of 1,241 pages, the annual index of authors and subjects occupying 208 pages in addition. Besides the usual sources from announcements and examination of new books, the unrivaled collection of current medical periodicals and transactions of societies and congresses, medical and scientific, in the Library of the Surgeon-General's Office, has been made available through the courtesy of the Surgeon-General of the Army. The title of every original article in these publications appears under its proper subject-heading month by month in the Index Medicus. Of the volume for 1906, the numbers to September, inclusive, have been issued.

BIOLOGY, EXPERIMENTAL.

DEPARTMENT OF EXPERIMENTAL EVOLUTION, COLD SPRING HARBOR, NEW YORK.*

By Charles B. Davenport, Director.

Two years of work at the station have been accomplished and that for the immediate future has been planned. It may now be advantageous to consider in general fashion what are the present aims of work in experimental evolution.

Man is philosophic. He looks for general principles and on the whole he acts on general principles. So his general theory of the world is of importance. It makes a real difference in his conduct whether he regards the world events as cataclysmic or as ever continuous and lawful. Consequently the work of Lyell in establishing the law of continuity in geology and the work of Darwin in establishing that law in organisms have revolutionized not only human thought but human action. This law of continuity, moreover, is necessarily applicable to human evolution. Neither physically nor psychologically is there a sharp break in the animal series where it culminates in man. Consequently the discovery of the laws of organic evolution is, at the same time, a study of human evolution. Since when we know the law we may control the process, the principles of evolution will show the way to an improvement of the human race.

A knowledge of the principles of evolution is advantageous in still another way. It shows how organisms may be best modified to meet our requirements of beauty, food, materials, and power. The carnation can be made not only crimson, but white, yellow, and blue; it can be made as large as a chrysanthemum or dwarfed. So the bantam fowl may be made of a red color, or black, or white; with a ruff or without; with a long tail or with no tail. Likewise the yield of wheat per acre may be doubled and the northern limit of wheat cultivation pushed poleward many miles each year. The egg yield of the hen may be raised from 150 to over 200 per year. The strength of cotton fiber may be improved and its length increased. The hardiness of fruits may be changed so that subtropical plants bear in temperate climates. The strength of the horse may be increased as that of the Percheron exceeds that of the Norwegian pony. In fact, by using the already known principles of evolution great practical advances have been made in the past. We are consequently justified in expecting that an extension of evolutionary principles will result in further advances in the future.

* Report for the year ending September 30, 1906. Grant No. 307. $21,000 for investigations and maintenance. (For previous reports see Year Book No. 3, pp. 23-32, and Year Book No. 4, pp. 87-107.)

While there can be no doubt of the practical importance of applying the known laws of evolution it would seem to be unwise for this station to devote its time to such work. There is no lack of practical workers. There are 56 State agricultural experiment stations where they may be found. Also the Federal Department of Agriculture maintains many practical breeders in the bureaus of Animal Industry and Plant Industry. Congress appropriates about $25,000 a year for the experimental gardens of the Department of Agriculture and $20,000 for the Arlington Experimental Farm. Finally there are thousands of plant and animal breeders in this country who are applying with more or less intelligence the established principles of the improvement of races. But all of these experiment stations and the individual breeders are held closely to work yielding immediate practical results. They apply known laws; they have no time or facilities for investigating in a calm and extended way those subjects that shall best reveal new laws. The work even of our experiment stations stands at the plane where it has been put by the workers in pure science. Their work in plant hybridization depends on the discovery of the sexual nature of the floral organs made over a century ago by the botanist Kölreuter and on the method and principles of crossing investigated by the plant physiologist Knight. Mendel, working in his cloister garden, was not concerned with making plants more beautiful or useful. But he established a new principle which is of inestimable value to breeders. He discovered the principle forty years ago; but it was overlooked by the practical breeder, and through thirty-five years of practical work was never rediscovered by the thousands of breeders or the scores of experiment stations. Now that attention has been directed to it it is being constantly used by practical men to get useful results. Had Mendel spent his time in improving some plant he would doubtless have succeeded, but he would have failed to discover his law. Mendel failed to accomplish the commonplace, but succeeded in discovering the new guiding principle.

So in the case of this Department. We could easily produce new and valuable races. We could do all these things with certainty by the application of well-known and constantly employed principles. But we prefer to risk certain results for the uncertainty of attaining new principles. A new theory may well be of much greater value than any improved race of plants or animals. It may affect the whole live-stock business whose cash value in America is very great. This commercial aspect is, however, rarely to be thought of. We propose to leave the question of application to others, bending our whole energy to our main work—the discovery of general principles or laws.

Our first two summers were largely spent in preparation for our work. Methods, many of them new, had to be perfected. Results are now com-

ing, but they must be tested repeatedly and many of them followed up for several years before they are reported upon fully. It may be well to consider in a general way the subjects we are investigating.

Inheritance of Characteristics.—One kind of organism differs from another, and the newly evolved species differs from its progenitor, in one or more characteristics. We have not reached the point where new characteristics can be produced at will, but we can learn the laws of inheritance of characteristics, and such knowledge will enable us to predict how a new variation will behave when crossed with the parental species and to classify variations according to their origin and behavior in heredity.

We find that when two varieties that differ in some characteristic are crossed it frequently happens that one only of the two forms will reappear in the offspring (viz, the *dominant* characteristic, of Mendel), and it will be little modified by the presence, in that offspring, of the germ of the opposite characteristic. This is in accordance with the theory that most characteristics are, or may be resolved into, elementary units. Similarly, when a variety that has some new feature not possessed by the ancestor is crossed with that ancestor the offspring usually have the character fully developed (dominant). If these offspring are crossed together the character is absent in a small proportion only, on the average one-quarter, of their offspring. The consequence of this law is that a newly evolved characteristic is not at once swamped by intercrossing, as has often been assumed, but may even spread at the expense of the parental type. Thus the new species is nurtured in its infancy.

Unit Characteristics.—The fact that in crossing varieties their dissimilar characters do not blend is important, since it supports the theory that such characters first appear as they now are, fully formed. It indicates that since evolution has advanced by the addition of new characteristics it had advanced by steps or jumps. A new species has not *gradually* arisen from an old one, but suddenly, by *mutation*. Our breeding experience, consequently, supports, in part, the mutation theory of de Vries. The practical consequence of this theory is that it is more important to look for sports or new combinations of characteristics than to work by selection.

On the other hand, it is becoming clear that unit characters are not immutable; for, in hybridizing, the dominant form often shows traces of its antagonist; and if the dominant form is repeatedly infected by continued hybridization it may become much changed.

Rôle of Selection.—Breeders attribute their success in improving races chiefly to the selection, for breeding stock, of the best-appearing individuals. Recently, a school has arisen which maintains that, within narrow limits, selection is impotent. Our results are giving us an exact insight into the truth of the matter and justify to a certain extent the breeder's operations while offering a new explanation for them.

Origin of New Characteristics.—This is the most important work in hand. If by any means new, inheritable characteristics can be brought out, then new races can be created. If characteristics can be induced of a desired sort, then evolution can be directed at will. Some of the new characteristics that we get are of the order of mutations and can not, at present, be predicted nor controlled. Others result from hybridization. Others still are induced by subjecting the parent to new conditions. As is well known, in the abnormal environment new characteristics arise; we are studying the method of inheritance of such new characteristics. There is reason for thinking that various agents may permanently modify the germ plasm; at least we are testing the matter.

Identity of Evolutionary Processes in Plants and Animals.—From its inception we have studied equally plants and animals in the conviction that evolutionary processes are similar in all organisms. Our experience so far has justified our conviction. It has been stimulating, in our weekly conferences, to note the parallelism of the results reported by those working with plants, insects, birds, and mammals.

WORK OF DEPARTMENTS.

The work with plants has hitherto been conducted solely by Dr. George H. Shull. Owing to his temporary assignment to study the work of Mr. Luther Burbank, Dr. E. N. Transeau, formerly of Alma College, Michigan, and earlier of the University of Michigan and of the University of Chicago, has been appointed to the resident staff. Dr. Transeau will continue many of the experiments started by Dr. Shull and will undertake in addition the study of adaptation in plants. For this work a set of instruments capable of analyzing the environmental factors will be required. The expansion of the botanical work has made it necessary to rent a parcel of land situated about a mile distant from the Station.

The investigations upon insects have made more rapid progress as the technical difficulties of breeding them have been overcome. They have proved excellent material for experiments on the influence of changed conditions of life. Valuable results have been gained on the inheritance of different types of variations. As the experiments have far outgrown the space available in the laboratory, a new vivarium is being built for them. Since the addition of an inexpensive helper has increased by several fold the scientific output of other departments, it is proposed to employ, next season, a vivarium boy to assist in the mechanical part of the insect work.

The work with domesticated races was five times as extensive this year as last, owing to the employment of a poultryman and the construction of fifty new breeding pens. Sixty distinct sets of experiments were made with poultry. Approximately 10,000 eggs were recorded, with few exceptions from exactly known mother and father. The number of chicks

hatched was 2,985; and more or less complete records were obtained also from about 3,000 chicks that developed but did not hatch. All of these have been described and the records tabulated to be used for immediate publication of results or to be held awaiting further information. The canary birds and finches have done well, 92 offspring having been reared. The births of the year include 6 goats, 6 sheep, and 20 cats. An additional step has been made toward the attainment of the particular combination in one cat of the characteristics named in my last report. Work with pigeons has been continued.

The cytological investigations have continued under the charge of Miss Lutz. Early in the year she was relieved of the work of secretary, which threatened to absorb her entire time, so that now she devotes herself wholly to investigation. She has gained results bearing on the infertility in buckwheat when like flowers are bred together.

COOPERATION WITH OTHER INVESTIGATORS.

The number of investigators working experimentally on topics in evolution continues to grow. We have been visited by workers from different parts of the country who have wished to inspect our work or consult on particular points and we have profited by visits to consult with and examine the work of others.

Our facilities have been extended to the following investigators who are not on the staff of the Station:

Dr. N. M. Stevens, of Bryn Mawr College, worked during the summer upon the germ-cells of Coleoptera and continued her experimental work on breeding plant-lice aphids. She was accompanied by Miss Alice M. Boring, of Bryn Mawr College, who worked on the germ-cells of hemipterous insects belonging to the family Membracidæ.

Prof. W. J. Moenkhaus, of Indiana University, continued his work on the breeding of flies to determine if the sex ratio can be modified by selective breeding and if there is a reduction in fertility and vigor in successive generations as a result of close in-breeding.

Prof. H. E. Crampton, of Columbia University, continued at the Biological Laboratory and the Station his work on selective breeding of the large Saturnid moths.

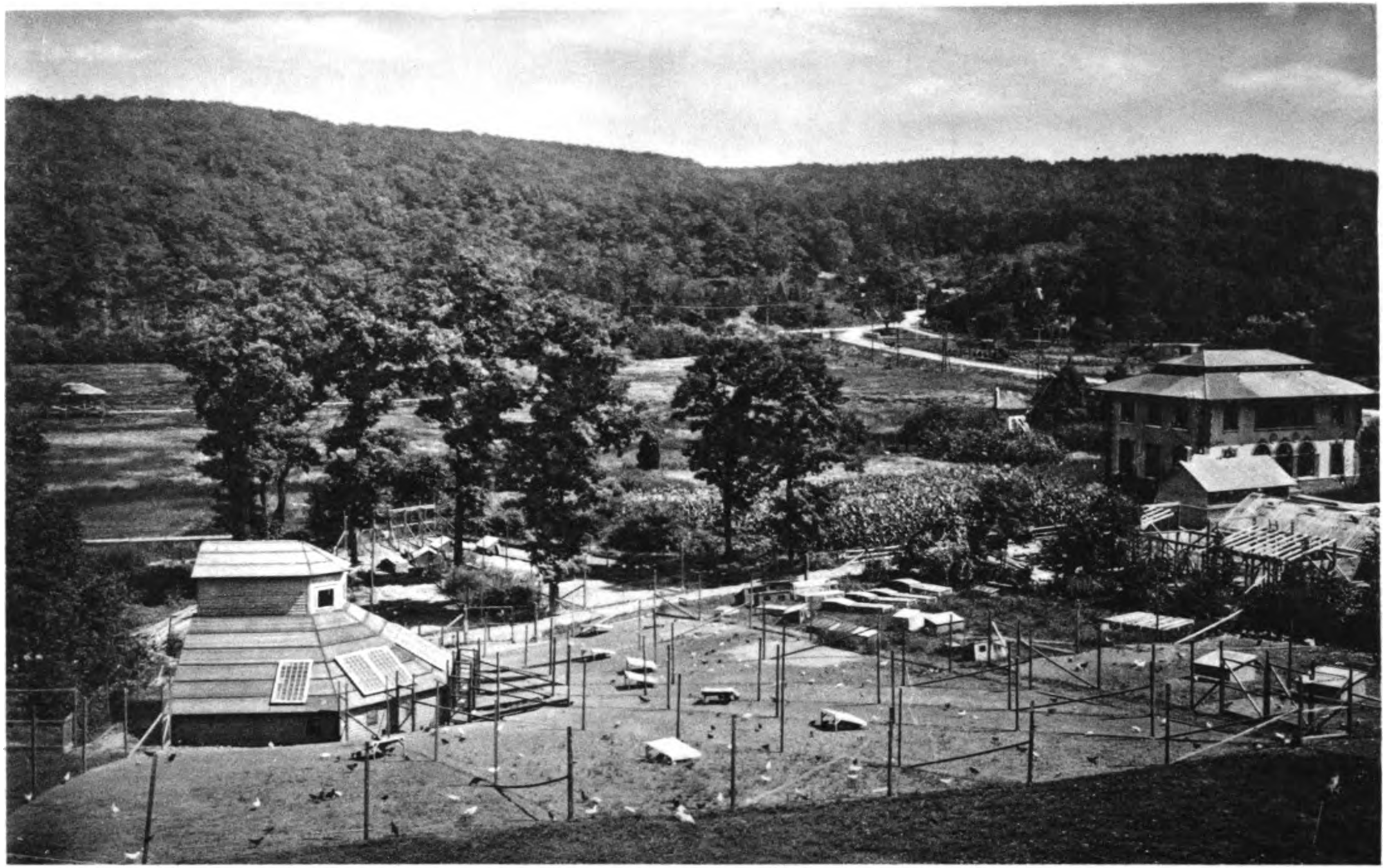
During the summer several of the investigators at the Biological Laboratory made use of the library and other facilities of the Station.

The following have been added to our correspondents:

Dr. Francis Galton, F. R. S., the well-known student of human heredity, to whom is due the introduction into biology of statistical methods.

Dr. Alfred Giard, professor at the University of Paris and director of the Laboratoire d'évolution des êtres organisées. To Professor Giard is due the conception in recent times of the establishment of an "Institut

PLATE 4



VIEW ACROSS COLD SPRING VALLEY LOOKING SOUTHEASTWARD, SHOWING PART OF THE GROUNDS OF THE STATION FOR EXPERIMENTAL EVOLUTION.

Main building at the extreme right, potting house and propagating house in front, and vivarium, under construction, in front of and to left of latter. To the left (north) of the main building is seen part of the east experimental garden. Near the extreme left is the brooder house, from which radiate eight poultry runs, seen in the middle foreground.

transformiste," an idea taken up in turn by the late George J. Romanes in England, and which has fruited in the present Station for Experimental Evolution.

Geheimrath Dr. August Weismann, professor of zoology at Freiburg. His well-known theories of evolution are guiding experimental investigations not only in his own laboratory but wherever such work is done.

Dr. Vernon L. Kellogg, professor of entomology at Stanford University, who has made extensive studies on variability in insects and has instigated a number of important investigations on inheritance in this group.

WORK OF SUBSIDIARY DEPARTMENTS.

The library remains an important adjunct of our work. The current journals are reviewed frequently and many of the ideas gleaned from them have been the starting points of new investigations or improved methods. The total number of bound volumes and pamphlets is 981, an increase during the year of 406. The library has been kept in fair shape by the attention during a few minutes of each day of one of the staff, supplemented by certain assistance paid for by the hour.

CARE AND DEVELOPMENT OF THE PLANT.

The main building proves to be highly satisfactory for our work. A smart blaze in the basement, due to the carelessness of a workman, occurred in the middle of the night, but was confined to the room in which it started by the fire-resisting nature of the construction. The small size of the building necessitates that it be used in the future almost exclusively for making, storing, and working over the records (including photographs) for the library and for the cytological and administration departments. The carpenter shop will be removed to a commodious building which we obtained at the cost of removal to its present site on our grounds. The plant cultures were transferred during the early winter to the new propagating house, which has proved of the greatest assistance in enabling us to hasten the succession of plant generations. The insect experiments at present occupy two large rooms in the main building. These experiments will be transferred to the vivarium, which is now being roofed in and will be ready for use in the spring. One of the rooms thus set free will be partitioned off into investigators' rooms. As soon as the bird house can be built the canaries now in the main building will be moved from it. Additional greenhouse room is demanded and will be provided as soon as feasible. The brooder-house was equipped in the spring with a heating plant and has been of the greatest assistance in rearing the young chicks. Forty colony houses for laying stock were erected on a lot near the Station grounds. They were made portable, so

as to be removable to another field if eventually acquired. An accessory water supply was equipped and has been used during the season for irrigation of the greenhouse and gardens.

As the work develops it becomes clearer that additional land will be needed in the near future.

The Station has this year as hitherto been the recipient of many gifts of interesting living plants and animals to be used for breeding and of use of land and materials to facilitate our investigations.

REPORT OF DR. GEORGE H. SHULL.

The studies on variation and heredity in plants have been continued along the lines indicated in my report for last year. The addition to our garden equipment of a greenhouse and an efficient gardener, both of which were available December 1, 1905, have increased by several fold the amount and value of the work accomplished during the year.

As compared with last year, there have been few failures in getting seeds to germinate, and the number of pedigrees which have come to fruition since October 1, 1905, is 291, belonging to the following 46 species. The number preceding each specific name in this list is the number of distinct pedigreed families studied in that species and the number following the name is the total number of individuals considered.

No. of families.		Individuals.	No of families.		Individuals.
3.	Commelina nudiflora L.	563	1.	Gentiana crinita Froel.	2
5.	Lychnis alba Mill.	1,521	1.	Solanum aff. lanceolatum.	6
2.	Ranunculus sp.	97	3.	Solanum aff. nigrum L.	162
2.	Chelidonium majus L.	354	1.	Lycopersicon lycopersicon (L.) Karst	25
2.	Eschscholtzia maritima Hort.	25	1.	Lycopersicon solanopsis White	25
3.	Eschscholtzia rosea Hort.	81	1.	Lycopersicon sp.	25
163.	Bursa bursa-pastoris (L.) Britton	17,532	1.	Verbascum thapsus L.	37
1.	Bursa heegeri (Solms)	23	1.	Mimulus ringens L.	367
2.	Fragaria sp.	50	1.	Digitalis sp.	161
1.	Lathyrus maritimus (L.) Bigel.	13	4.	Plantago lanceolata L.	266
1.	Polygala polygama Walt.	3	2.	Plantago major L.	180
3.	Viola arvensis L.	47	1.	Dipsacus sylvestris Huds.	114
1.	Viola papilionacea Pursh.	12	15.	Ambrosia artemisiæfolia L.	902
4.	Viola spp.	29	1.	Chrysopsis argentea Small.	9
1.	Oenothera biennis L.	83	1.	Chrysopsis graminifolia	52
6.	Oenothera cruciata Nutt.	87	2.	Erigeron ramosus (Walt) B. S. P.	180
3.	Oenothera gigas De Vries	439	7.	Rudbeckia hirta L.	382
16.	Oenothera lamarckiana Ser.	2,172	13.	Helianthus annuus L.	929
2.	Oenothera lata De Vries	355	1.	Helianthus debilis	93
2.	Oenothera nanella De Vries	244	1.	Helianthus petiolaris	5
4.	Oenothera rubrinervis De Vries	1,038	1.	Gaillardia pulchella pieta Gray.	115
1.	Oenothera sp.	11	2.	Erechtites hieracifolia (L.) Raf.	180
1.	Clarkia pulchella Pursh	81			

In the continuation of my investigations into the fluctuations of *Oenothera lamarckiana* and those of its mutants, about 18,000 measurements have been made on the buds from fifteen different pedigreed families of Oenothera, representing particularly different treatment as regards

cross- and self-fertilization. In the cross-fertilized series care is being taken to introduce newly arisen mutants wherever possible.

The second generation of hybrid beans is being harvested, and enough have been examined to show that the latency of a mottled color pattern and a pigment darkener in the white variety used in these crosses was correctly assumed. This allowed the prediction that in the second generation between white and yellow beans, for instance, there would be found some individuals which would produce only plain black beans, and some only yellow mottled ones, though neither form probably occurred in the recent ancestry on either side of the pedigree. The prediction has been realized, but whether the proportions will approximate those expected can be seen only when the investigation of the several thousand hybrid individuals has been completed. In addition to these expected results there are a few individuals which belong to none of the predicted classes, and these may indicate the presence of other latent characters not detected in the first generation because they were recessive. Owing to the lack of facilities for guarding against cross-fertilization, this point can not be satisfactorily determined.

Besides these hybrid beans, the following hybrids have been under observation during the year: *Lychnis alba* Mill. (purple × white and reciprocal), *Eschscholtzia rosea* × *maritima* Hort., *Bursa bursa-pastoris* (L.) Britton (several elementary species), *Bursa bursa-pastoris* × *heegeri* and reciprocal, *Verbascum blattaria* L. (white × yellow), *Verbascum thapsus* × *blattaria*, *Helianthus annuus* L. ("Russian" × Western native). With exception of the last, the results of these hybridizations generally agree with what might be expected upon the basis of certain theoretical considerations. Arrangements have been made to continue these hybrid combinations and in addition an apparently successful attempt has been made to secure hybrid seeds of *Lycopersicon lycopersicon* (L.) Karst and *L. solanopsis* White.

From May 15 until July 15 I was absent from the Station for the purpose of studying the valuable horticultural work of Mr. Luther Burbank. Notwithstanding the devotion of those left in charge of the cultures during this time, several of them suffered irreparable injury. The most unfortunate of these involved the "pure line" beans, and as I am likely to be absent for considerable intervals during the next several years, it seems best to abandon this experiment until such time as satisfactory conditions for control may be attainable.

Most of the specimens collected during 1905 for the herbarium have been mounted. These are distributed as follows: The flora of Cold Spring Harbor, Long Island, 480 specimens; pedigreed plants, 452 specimens; seedling and juvenile forms, 12 specimens; abnormalities, 22 specimens; total, 966 specimens.

REPORT OF MR. F. E. LUTZ.

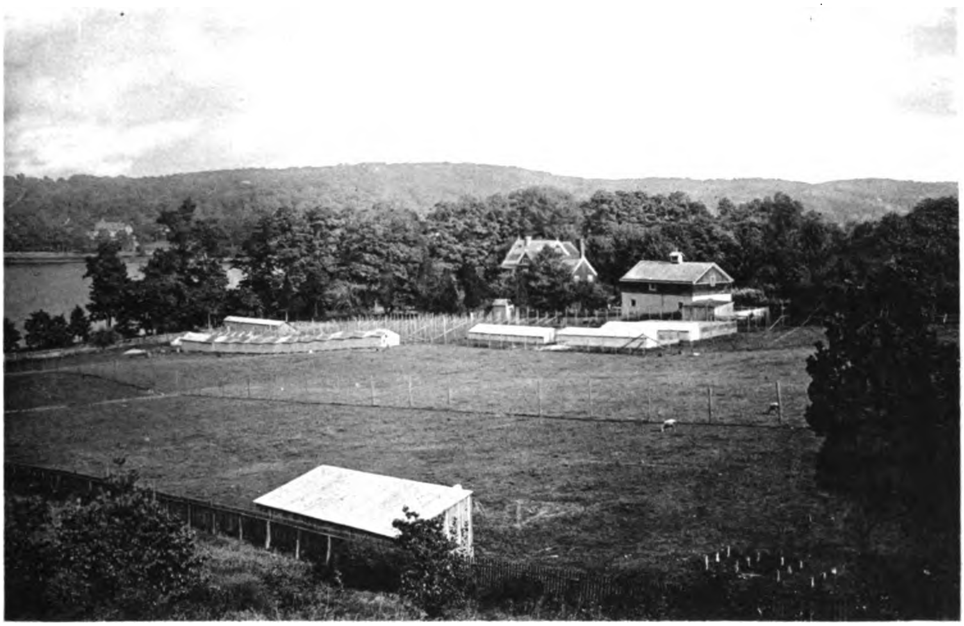
The work outlined in the last report has been conducted on as large a scale as circumstances permitted. The principal insects used have been *Hyphantria cumea* (fall webworm), *Gryllus* sp. (cricket), and *Crioceria asparagii* (asparagus beetles). As in former years, trials have been made of other species to determine their fitness for the work in hand, especially their adaptability to laboratory conditions. In arranging these conditions the aim has been to devise schemes which will, as nearly as possible, make the pedigree insects take care of themselves.

The chief point in the work with *Hyphantria cumea* was originally to test the inheritance of the dichromism of the larvæ which is so generally figured. The two forms, however, were not found distinct. The facts of the case seem to be that the larvæ reach their full pigmentation very slowly after each molt, and the presence of a large number of newly molted, partly pigmented larvæ in a nest containing also fully pigmented individuals has given rise to the notion of light and dark forms. Only one individual, out of several hundred that were watched, pupated before the full pigmentation after the last larval molt was reached. This was probably a pathological case. It died as a pupa. Individuals may be found, however, which are normally light throughout larval life. This phase of the experiment has not been abandoned. Meanwhile attention is being paid to the color variations of the adult which are considered by some to constitute differences of specific rank.

The biometric studies of Gryllus have been continued. It is hoped that they may be valuable in themselves, but more so as a basis for experimental work on the inheritance of fluctuating variants, provided the technique of breeding Gryllus can be mastered. The pedigree strain was all but lost this season through ignorance of the fact that the over-wintering eggs almost require freezing for their proper development. No time was gained by "forcing" the hatching and much material was lost. Those individuals which did mature, of the lot hatched in January, matured only several days earlier than their cousins which had passed the egg state out of doors and hatched in June. Selection and different methods of forcing will, nevertheless, be tried, both for their theoretical interest and the practical importance of getting a rapidly breeding strain; but the majority of the eggs will be kept this winter under perfectly normal conditions lest the strain developed during the past several summers be entirely lost. The above remarks apply to the native Gryllus. *Gryllus domesticus* has also been experimented with and has multiplied very satisfactorily under severe laboratory conditions. Pedigree cultures have been started. Crosses between *Gryllus domesticus* and our native crickets proved sterile, as expected.

The main work of the summer months has been with *Crioceris asparagii.* They hibernate as adults and become active at Cold Spring Harbor

NEAR VIEW OF PART OF THE WEST EXPERIMENTAL GARDEN, WITH PROPAGATING HOUSE IN THE BACKGROUND.



VIEW OF "NORTH LOT" WITH ITS 62 POULTRY RUNS AND TWO SHEEP AND GOAT PASTURES.

about the middle of May. The grandchildren of these hibernating adults mature in late August and early September and then hibernate, although a few lay eggs which give rise to a weak additional generation. Without much doubt, then, a three-generation-a-year strain can be developed. The beetles are fairly easy to rear. The chief difficulty has been the danger of introducing wild eggs or larvæ with the food. It is planned to grow the food next summer under glass and also inside of a large netting tent in the garden. A study of the inheritance of the 3-brooded *vs.* the 2-brooded condition may prove interesting; also the inheritance of various physiological characters. The main objects of the experiment, however, are to test the inheritance of the color pattern and to attempt to find out the cause of the variation which ranges from light spots on a dark ground to dark spots on light ground. The range already worked with is shown in the accompanying figures.

a *b* *c* *d* *e*

Pattern *a* acts as a Mendelian dominant to patterns *c*, *d*, and *e*. A special study of the variable recessive group and an analysis of pattern *b* will be attempted next season. The lighter forms are southern. This fact would point to a relation between temperature and color pattern. A little work was done along this line this summer and more will probably be done next. The possibility of changing at will definitely inherited color patterns by slightly altering temperature conditions is worth investigating.

During the winter certain biometric work will be carried on; also a study of the color pattern of *Crioceris asparagii* from morphological and phylogenetic viewpoints. Material for these investigations is being procured.

REPORT OF MISS ANNE M. LUTZ.

In order to repeat under more favorable conditions the experiments undertaken last year with the buckwheat (*Fagopyrum fagopyrum*), a new lot of 52 plants was grown in the greenhouse, blossoming in April and May. It was possible here to guard securely against pollination by insects and to be certain of results. This first lot produced such an excess of abnormal blossoms that it was considered unreliable material for preservation and was abandoned; the second potting of 110 plants came to bloom in June. The primary object was to fix material for histological study which would throw light upon the sterility of long-

styled plants to pollen from long-styled, and of short-styled to short-styled. Before proceeding, however, it was thought advisable to ascertain whether this sterility was an infallible rule. Previous to the opening of the first blossom, all plants were securely bagged against stray insects or flying pollen, and in every case possible blossoms were castrated before anthers opened, with the exception of such as were to be used for pollinating purposes.

In this manner 22 long-styled plants were operated upon, pollinated in each case with its own or, in a few cases, with pollen from another long-styled plant. Of this number (ranging from 1 to 30 blossoms each), 12 plants set seed, varying in number from 1 to 5 each and in degrees of maturity to which the seed attained. In all 218 long-styled blossoms were self-pollinated, and 21 of these produced seed; 17 short-styled plants were similarly operated upon, and 7 of these set seed in numbers ranging from 1 to 13. Of the 73 short-styled blossoms self-pollinated, 12 came to seed. All seeds so produced were planted in sterilized soil, and, with the exception of a small percentage which sprouted before planting, all grew. The experiment will be repeated on a much larger scale this autumn in order to have larger numbers from which to obtain percentages of successful self-pollinations; to obtain seed of self-pollinated material to plant for study of inheritance; to experiment with possible parthenogenetic development, and, primarily, to obtain material for the study of the histological problems in connection with these experiments.

The attempt to hybridize the two species of *Gastroidea cyanea* and *polygoni* reported upon last year was repeated this spring. No offspring were produced, although hundreds of supposed hybrid eggs were obtained which developed quite normally for about three-fourths of the incubation period. Upon examination of eggs of virgin females, however, they were found to have developed parthenogenetically in the same manner, a number showing eyes, body segments, and appendages quite distinctly. Material has been fixed for the cytological problems in connection with this experiment.

A study of the cytological phenomena to be observed in connection with the sterility of certain selected insects has not yet progressed sufficiently to report upon.

REPORT OF MR. ROSWELL H. JOHNSON.

The past year has shown that it is possible to provide lady-beetles with their food (plant-lice) and to breed them the year around. The necessary experience has been acquired concerning the best species of plant-lice to raise indoors and in the garden, and the hosts, seasons, and availability of those found wild. The death rate of the lady-beetles in confinement has been rather high, the progeny were sometimes sterile, and egg-laying has been interrupted at times. These adverse conditions will be some-

what mitigated in the future by the experience which has been gained and the more favorable temperature and arrangement in the new vivarium. Although the difficulties are such that it is generally necessary to start several pairs to rear progeny to maturity from one, the especial advantages of this material as shown in the last report have led to satisfactory results.

In addition to lady-beetles, I have undertaken similar work in another section of the Coccinellidæ, viz, the squash-beetles. Although less favorable from the fact that there are but three species in the United States, the ease with which large series are raised and the variation of its color pattern make it desirable for some lines of work.

In order to ascertain if the laboratory conditions would in themselves produce modifications, pedigrees were started from normal specimens of our local species of lady-beetles. With one exception, to be pursued further, there has been no change.

Normal specimens of other species from distant localities have been bred, in one case for several generations. No modification has resulted. *Adalia frigida* var. *ophthalmica,* from Springfield, Mass., produced some progeny of the varieties *disjuncta, ornatella,* and *annectans,* but these were probably predetermined.

Attempts have been made to modify most of the species available by increased dryness, moisture, heat, and cold. In contrast to the usual negative results is the effect of cold applied intermittently to *Hippodamia convergens.* The effect is an increase of the black markings along definite lines, particular spots being prolonged in definite directions in a definite order. Heat was effective only in the case of the squash-beetle, in which the pattern of the wing-cover remains normal; but the black markings of the thorax are all reduced, producing the conditions found in specimens from Texas.

Hybrid pedigrees have been started in the following cases: *Hippodamia convergens* × *H. c.* var. *ambigua;** *Hippodamia convergens* × *H. c.* var. *extensa;** *Hippodamia convergens* × *H. c.* var. *juncta;** *Adalia frigida* var. *ophthalmica** × *A. f.* var. *disjuncta;** *Coccinella novemnotata* × *C. n.* var. *confluens;* and between various unnamed forms of *Epilachna borealis* and *Hippodamia convergens.* In general it may be said that the inheritance is alternative in some cases, and in other cases *some* of the progeny are intermediate. A Mendelian segregation is found in subsequent generations in some cases, but so far these have shown some individuals with the parental characteristics modified.

The following closely allied species and others less allied were intersterile: *Hippodamia convergens* × *H. glacialis; Coccinella californica* × *C. monticola.*

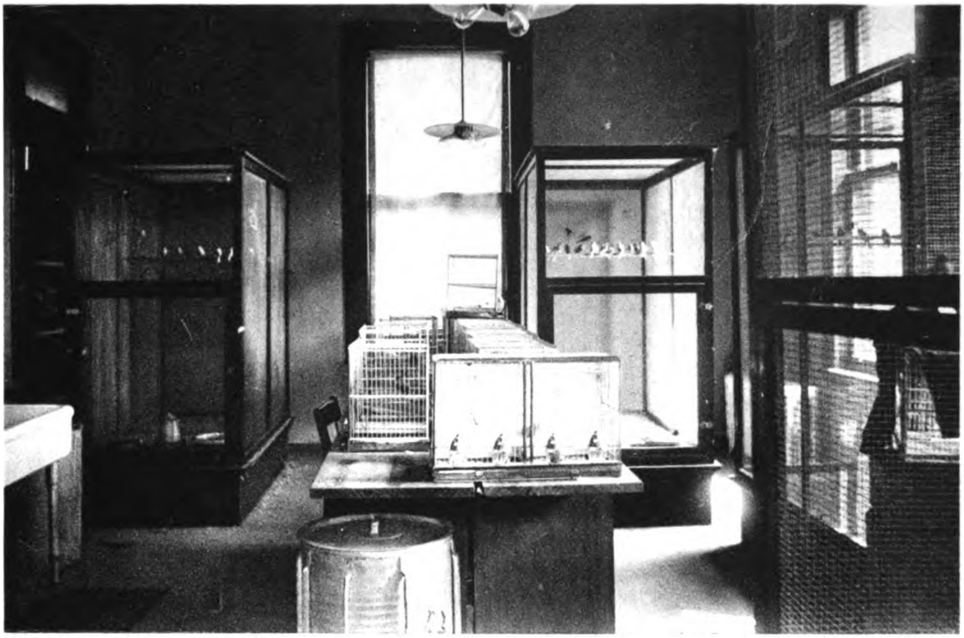
* Considered species by Casey.

When time was available from the breeding work, the variation and geographical distribution of the genera used were investigated and my own collection much enlarged. The collections in New York, Philadelphia, and Washington were studied. A lot of 15,415 Hippodamiæ from the top of Kamiack Butte, Washington, was classified into categories and the intermediates arranged. The distances between spots, the thickness of the connections between spots when joined, and correlations of a lot of 334 Hippodamiæ from Fairfield, Washington, were studied statistically. These results, which were to have been published this past spring, I have decided to publish later with the experimental work. The lady-beetles when disturbed exude from some joints of the legs a fluid tasting like aloes. That this is really distasteful to birds I have found by experiment. The spots upon the lady-beetles have been supposed to be association marks by which the birds may avoid lady-beetles and the beetles thus profit. But if this were true, variations from the pattern in the directions of loss or fusion would be eliminated. Yet in most parts of the United States the spotted *Hippodamia convergens* occurs along with some of its forms or closely related species which show fusion of spots, and in parts of California and Oregon with a form that is spotless. In California, where the spotted and spotless forms are together, a number of mated pairs which I collected showed no evidence of preferential or assortative mating. It would seem, therefore, that the evolution of the color-pattern in these beetles is not the result of selection, but that here we deal with evolution resulting from progressive variation or from mutation associated with dominance and imperfect segregation. The fact that *Coccinella transverso-guttata, C. trifasciata,* and *Hippodamia convergens* all have their spotless forms in the same locality would make it appear that the origin of the new forms is the result of direct alteration of the germ-plasm by the environment in these cases. These beetles therefore seem to be in the very condition which most needs investigation.

An incidental result of my hunt for aphids has been the discovery of some on plants which do not seem to be recorded as hosts. This with information as to the preferences shown by some lady-beetles for some aphids and distaste for others and as to the parasites of lady-beetles may be of use to economic entomologists and will be published separately where accessible to them.

The following statistics give some idea of the extent of work done:

Controlled matings	205
Of these, fertile eggs obtained from	22
Number of females isolated (from the field)	74
Fertile eggs obtained from	49
Progeny reared successfully	498
Pupæ brought in from field for modification experiments and emerged	74
Pupæ collected in field for observation, emerged	117
Larvæ now developing	73



INTERIOR VIEW IN MAIN BUILDING, SHOWING ROOM DEVOTED TO BREEDING CANARIES AND OTHER CAGE BIRDS. THERE ARE ABOUT 175 BIRDS IN THE ROOM.

INTERIOR OF PROPAGATING HOUSE, SHOWING PEDIGREED CULTURES OF PLANTS.

REPORT OF DR. E. N. TRANSEAU.

Since coming to the Station in July most of my time has been spent in the study of the local plant societies. Especial attention has been given to those species which occur in more than one habitat, as they will probably furnish the material for future experimentation. Herbarium and alcoholic specimens of these plants have been collected for a further study of their structural variations. It is hoped that this work will point the way to field experiments on habitat modifications and selection.

On the other hand, several species are being cultivated in order to determine the range of their variability in a single habitat. When the habitat experiments are begun, it is hoped that they may be conducted with pedigreed seeds of plants whose variation in a single habitat is known.

In order to differentiate the effects of the various soil and meteorological factors, measurements by means of recording instruments should be made throughout the growing season. When the habitat characteristics and their united effects on plants are known, control experiments in the plant-house will aid in the separation of the individual factors.

REPORT OF DR. W. J. MOENKHAUS.

During the past two years my work has been principally on the sex ratio in Drosophila, with especial reference to its control by selection. Data on over 10,000 individuals have been obtained; most of this is pedigreed. I consider the results sufficiently definite to warrant publication and they are about ready for the press.

REPORT OF DR. N. M. STEVENS.

My work at Cold Spring Harbor was a study of the germ-cells of Coleoptera, with reference to the problem of sex determination; also some observations on aphids with reference to correlation of color with sex. I also began studying the banana-fly in connection with the same problem—sex determination.

Miss Boring, who was with me for six weeks, was making a comparative study of the germ-cells of several families of the Hemiptera-Homoptera, especially the Membracidæ, Fulgoridæ, and Jassidæ.

BIOLOGY, MARINE.

DEPARTMENT OF MARINE BIOLOGY, TORTUGAS, FLORIDA.*

By A. G. Mayer, Director.

The laboratory yacht *Physalia* remained moored in the Miami River throughout the hurricane season of 1905, and in February she was thoroughly overhauled and refitted. An awning was constructed to extend from stem to stern, thus shielding the decks from the intense heat of the tropical sun. The decks were recalked and varnished. The engine was placed in the best possible condition, and the exhaust pipes were renewed where corrosion had attacked them. The vessel was also provided with large hood ventilators which are a necessity in the tropics, in order to permit of microscopic studies being carried out in the cabin. The yacht was also hauled out and her hull found to be free from the attacks of Teredo; and in order to better insure her safety in this respect the brass sheathing was made to entirely incase her keel, and a false keel was placed on for protection in the event of her going aground.

In addition to these extensive repairs and alterations in the *Physalia* a new launch, the *Sea Horse*, was constructed for the Department by Stearns & McKay, of Marblehead, Massachusetts, and shipped to Key West early in March. This launch is designed to withstand heavy weather in the open sea in order to transport investigators to and fro between Key West and Tortugas. She is 27 feet long, and is furnished with two 6-horsepower naphtha engines, and with twin screws, thus insuring her against the probability of a total breakdown of her machinery while at sea. This launch is provided with a comfortable cabin, and can travel more than 400 miles with her supply of naphtha. She develops a speed of 8 knots in average weather, and owing to lack of spars and top hamper she is but little retarded by head winds.

The Department is thus provided with five boats, the 58-foot 20-horsepower ketch *Physalia;* the 27-foot twin-screw 12-horsepower cabin launch *Sea Horse;* a 22-foot 4-horsepower dory; a small 1-horsepower launch, and a rowboat.

With these vessels it is possible to cruise anywhere within 150 miles of the laboratory; the *Physalia* being a thoroughly seaworthy vessel designed especially to withstand West Indian hurricanes.

Prof. William K. Brooks and his assistant, Mr. Carl Kellner, of Johns Hopkins University, joined the *Physalia* at Miami, Florida, in March, and a few days were spent in a study of the pelagic fauna of the Gulf

* Report for the year ending September 30, 1906. Grant No. 308. $15,000 for investigations and maintenance. (For previous reports see Year Book No. 3, pp. 50-54, and Year Book No. 4, pp. 108-124.)

Stream in the neighborhood of Miami. Professor Brooks also collected specimens in the Everglades which have enabled him and his assistant, Mr. B. McGlone, to determine that the lung of Ampullaria is secondarily acquired, and not derived from the lung of terrestrial pulmonates. The details of this discovery are recorded in Professor Brooks's preliminary report, here published.

After about one week's exploration at Miami, the *Physalia* sailed for the Tortugas, where she was employed throughout the season in making surface hauls and dredges. Mr. Kellner discovered a remarkable "calm streak" extending along the 6-fathom line on the westward side of Loggerhead Key, and examinations of this region on calm days yielded a wonderful variety of new and rare Siphonophoræ, Ctenophoræ, pelagic, and Medusæ, as well as a good collection of pelagic Tunicates.

Early in the calm mornings, when the ocean was unrippled, hosts of graceful Siphonophoræ and delicate Ctenophoræ came up out of the depths to the quiet surface, and in fifteen years of study the writer has never seen such opportunities for the collection of these remarkable marine animals.

Five heavy gales were encountered during the season. The first of these came suddenly without barometric warning on the first day of our arrival at Tortugas, before we could lay our ocean mooring, which is necessary to secure the *Physalia*, as she must lie at anchor throughout the season in an open roadstead with no protection save that afforded by a deep-lying coral reef. The storm came with almost unprecedented suddenness, and the wind blew for more than six hours at the rate of over 60 miles an hour. Our kedged anchors were powerless to hold the *Physalia*, and she slowly dragged until her stern touched the shore, while our 22-foot dory launch was dashed open in the breakers. Fortunately the wind then abated for a few minutes, and the *Physalia* was hauled off without damage. The launch was repaired in the course of a few weeks and is now a stronger and a better seaboat than ever before. Other storms came later, one of them of such severity that nearly all of the beacons in the lower part of the Hawk Channel were washed away, but our strong moorings and opportune retreats into Bird Key Harbor enabled us to ride safely through every gale.

Eight investigators studied at the laboratory during the season, and every one returned north with health improved. Our facilities for transportation afforded by the many boats in the service of the Department now permit us to transport students at once from Key West to Tortugas; and thus they are not subjected to the menace occasioned by the deplorable sanitary condition of Key West. In the pure dustless air of the Tortugas, with its freedom from dangerous mosquitoes, nothing need be feared, and it is significant that no infectious disease has ever developed

among the lighthouse keepers or their families during the many years that the lighthouse has been maintained on Loggerhead Key. In order, however, to insure against the possible introduction of tropical fevers our cisterns are rendered mosquito-proof, modern plumbing is introduced, and all refuse from the kitchen is daily towed out to sea. No mosquitoes breed upon Loggerhead Key, but in order to afford protection against those which are carried upon the island by the wind, mosquito nets of the best pattern are provided, so that investigators may enjoy all possible protection. Whenever the wind blows from the direction of the Florida Keys a few Culex mosquitoes appear, although these must be blown at least 40 miles from the Marquesas Keys in order to reach the Tortugas. After arriving at Tortugas there is practically no danger of contracting any tropical disease, but in order to warn students of the dangers one may expect to encounter in hot, crowded, tropical cities, the following circular was issued to each investigator who purposed to visit Florida in summer:

SUGGESTIONS FOR CARE OF HEALTH IN THE TROPICS.

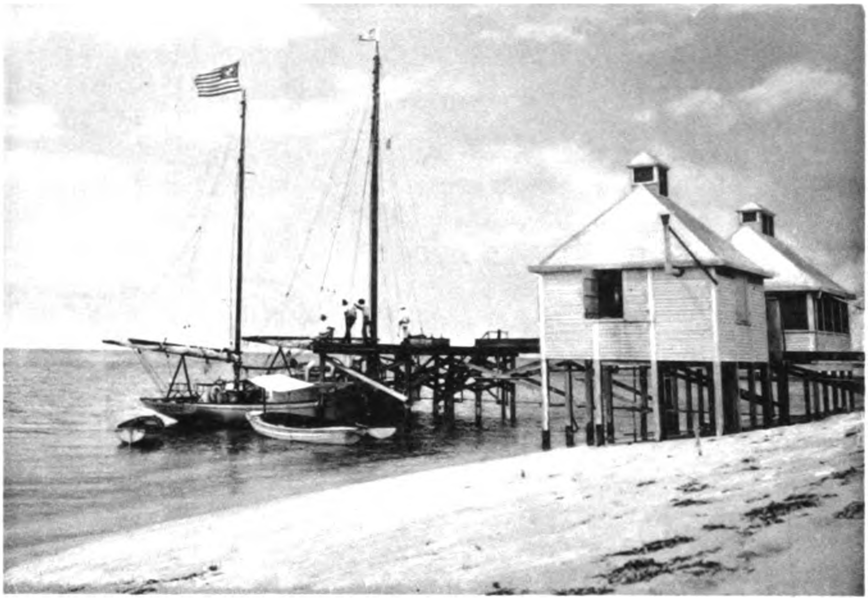
These suggestions apply especially to life in tropical cities such as Key West, Tampa, Miami, New Orleans, or Havana. At Tortugas, Florida, no unusual precautions are necessary, for the islands are securely isolated from infectious diseases, and no mosquitoes breed upon Loggerhead Key.

1. Go to bed as soon after sunset as possible, and always sleep under a mosquito bar. Examine the mosquito net before nightfall, and kill all mosquitoes entrapped under it. Then tuck the net in all around the mattress.
2. Drink only boiled or imported waters. If you can not obtain these, put lime or lemon juice into the water. Do not drink too much ice-water.
3. Rest for a few days when you first arrive in the tropics. Do not exercise too actively or remain too long in the hot sun.
4. Eat peeled or cooked fruits, but avoid raw, unpeeled fruit.
5. Any excess in the tropics is attended by more serious consequences than in temperate regions.

The following investigators pursued researches at the laboratory during the season:

Prof. W. K. Brooks, of Johns Hopkins University, March 15 to April 2.
Dr. Leon J. Cole, of Harvard University, May 31 to June 20.
Dr. R. P. Cowles, of Johns Hopkins University, June 22 to July 20.
Prof. Ulric Dahlgren, of Princeton University, June 22 to July 20.
Dr. C. H. Edmondson, of Iowa University, June 19 to July 20.
Mr. Carl Kellner, of Johns Hopkins University, March 15 to July 20.
Prof. Edwin Linton, of Washington and Jefferson College, June 28 to July 20.
Dr. Charles Zeleny, of Indiana University, June 12 to August 1.

The duration of the average visit to the laboratory was forty days. Hitherto it has been necessary to close the laboratory before August 1, for by the terms of her insurance the *Physalia* must be laid up in a safe



THE "PHYSALIA" AT THE DOCK OF THE TORTUGAS LABORATORY, JULY, 1906.

VIEW OF THE MAIN LABORATORY BUILDING FROM THE NORTH, JULY, 1906.

harbor before this date. In 1907, however, it will be possible to maintain the laboratory open after August 1, making use of the *Sea Horse*, after the *Physalia* has been laid up, and thus the season may be very profitably lengthened; for very few students can arrive at Tortugas before the third week in June, and the working period is too short for extended researches such as the laboratory purposes to encourage.

THE WORK OF THE LABORATORY.

During the season of 1906 the following researches were carried out:

Prof. William K. Brooks and his assistant, Mr. Carl Kellner, devoted much time to collecting Salpæ and Appendicularia for the extensive memoir upon which Professor Brooks has for some years been engaged. Mr. Kellner spent four months in making surface hauls, and obtained many excellent specimens of Salpæ, which he preserved in the best possible manner for future study. It is hoped that this collection will be of material aid to Professor Brooks in the preparation of his important work upon the relationships of these animals. Mr. Kellner also made a special study of the structure of the house of Oikopleura. While visiting the Everglades near Miami, Professor Brooks collected the eggs of Ampullaria the study of which forms the topic of his preliminary report, here published.

The Origin of the Lung in Ampullaria, by W. K. Brooks.

Through the courtesy of Dr. Alfred G. Mayer I was able to visit and partially explore the Everglades of Florida in March, 1906. As we pushed our way through the tall reeds and grasses that cover the shallow water of the Everglades, we found great numbers of small eggs, attached to the stems of the reeds and grasses, above the surface of the water but close to it.

The eggs were arranged in vertical rows, and were inclosed in calcareous shells, resembling, in these respects, the eggs of terrestrial pulmonate gasteropods.

We also found in the water in great abundance the prosobranchiate gasteropod Ampullaria, and when some of the older eggs were opened, they were found to contain young specimens of this genus.

The Paludinidæ, which are closely related to the Ampullaridæ, are aquatic, viviparous, and breathe by gills; and their structure indicates that they are true prosobranchs, descended from and closely related to the marine prosobranchs. Ampullaria has gills, is partially aquatic, and seems to be a true prosobranch, so far as its general structure is in question; but as it has a lung, and is able to breathe air and live out of the water, and as it also lays, in the air, eggs in calcareous shells, like those of the terrestrial pulmonates, the question whether it is primarily a pulmonate, with secondary resemblance to the prosobranchs, or primarily a prosobranch with secondary resemblance to the pulmonates, suggests itself.

As the embryonic history of the breathing organs may be expected to throw light upon this question, a quantity of the eggs was collected and taken to the Marine Laboratory in the Dry Tortugas. There the eggs were opened, the embryos removed and sketched, and then hardened and preserved for embryological examination.

On my return to Baltimore, I placed the material in the hands of Mr. B. McGlone, who has studied the development of the respiratory organs under my supervision, and has nearly completed his work, which will soon be ready for publication. He has shown that the lung of Ampullaria is a member of the series of gill-filaments and that it must be regarded as a modified gill, homologous with a ctenidium, or with more than one. It is, therefore, an organ which has been secondarily acquired, and not derived from the lung of the terrestrial pulmonates.

Both lung and gill arise very early in the embryonic history of Ampullaria, and at about the same time. In a very young embryo, soon after the mantle makes its appearance, a ridge or thickening of the epithelium of the inner surface of the mantle indicates the region from which the gill-filaments, the lung, and the osphradium are to arise. The osphradium is developed from one end of this ridge, the gill-filaments from the other, and, between the two, the ridge becomes infolded into the substance of the mantle to give rise to the lung, which may be regarded as a modified and invaginated gill-filament.

The similarity between the lung of the pulmonates and that of Ampullaria is, therefore, nothing more than a new illustration of a resemblance between organs that have been acquired independently under like physiological conditions.

Mr. Kellner presents the following report of his work:

The Appendicularias of the Dry Tortugas, by Carl Kellner.

In May, 1906, I captured a number of appendicularias, and their houses, near the surface of the water in the Dry Tortugas, and I am informed that similar ones were found at Miami in March by Dr. Mayer and Professor Brooks. They vary in size from 5 to 8 mm., and they occur in great swarms at a depth of from 5 to 8 fathoms. Since returning to Baltimore, I have been studying them under the guidance of Professor Brooks, with special attention to the structure of the house and the anatomy and histology of the animal. My notes and drawings will be ready for publication within a month. All my large specimens belong to the genus Oikopleura and are very similar to, but different from *Oikopleura longicauda* and *Oikopleura intermedia* of Lohmann.

The house is large, about 20 mm. in diameter, and nearly spherical. In its internal structure it resembles the houses that have been described in other species of the genus.

Some of the houses contained small appendicularias at various stages of development, and there is no doubt that the development of this species may be studied by one who is able to collect and study the young larvæ and embryos from the houses of living adults, but those that I have found in preserved houses are not in good condition.

All the houses that I examined contained small elongated unicellular parasites; and others, of a somewhat different shape, were found on the tails of some of my specimens, and still others in the muscles of the tail. These three forms may prove to be stages in a single life history The parasites that are found on the tail are very similar to, and seem to be identical with, the bodies that are described by Lohmann as gland cells.

Dr. Leon J. Cole studied the reactions of ants and of *Salpa democratica*, but his work is not far enough advanced for publication.

Dr. R. P. Cowles continued his studies of the habits of the ghost crab (*Ocypoda arenaria*) and also of the reactions of Ophiuridæ. His results are important and interesting and will soon be published.

Prof. Ulric Dahlgren presents the following report of his studies:

Report of Work Accomplished by Ulric Dahlgren in the Laboratory of the Carnegie Institution at the Dry Tortugas, Florida, during the Summer of 1906.

On June 20 of this year I arrived at Key West. My object in visiting the laboratory was to procure material from *Pterophryne histrio* and other pediculate fishes to continue my studies of the giant ganglion cell apparatus found in this and other fishes. Also I wished to secure living specimens of Astroscopus to study the electric organs with the Golgi method and the intra-vitam method with methylene blue.

On the second day we proceeded to the Tortugas and were soon collecting on the reef. I found an abundance of Pterophryne, and secured a splendid series of these fishes prepared in all ways necessary for my work.

Of Astroscopus, however, I did not succeed in getting a single specimen. Liberal rewards offered in Key West to the fishermen, expeditions in the *Physalia* to the neighboring keys, and as unremitting a search as the climate permitted alike failed to procure a single individual of this fish. The fish has been reported from Key West, but the native fishermen there agree that it is not often found on the Florida Keys, and is more abundant on the west coast of Florida than anywhere else that they know of. Mr. C. F. Silvester, who is working in collaboration with me on the electric organs of Astroscopus, has, however, secured three specimens of the fish this summer at Beaufort, North Carolina.

Reef-collecting on the Tortugas affords a wonderful opportunity. No one who has not waded on a coral reef can imagine the wealth of life found there. This is not apparent from a surface view, however, as the coral reef fauna, with a few exceptions, is hidden in the many crevices of the rock. In general the fauna was of two distinct kinds. On the reef south of Garden Key an outer fauna was to be found on the south side, where the exposure was toward the ocean, while on the northwest side a different assortment of animals was to be found on the reef in the quieter and shallower waters of the lagoon and channel.

The pelagic surface collecting was grand, and more can be learned of this from the report of Dr. Mayer and those who followed it up. Pterophryne was the one form that I sought and I secured many specimens in person and from the other collectors who brought them in.

Among other features of interest were the swarming of the Atlantic Palolo worm on July 11 and 12, and of which many of us got series of eggs and embryos, and the frequent nesting of the turtles on the beach at night. For one working on the embryology of the reptilia this would be an ideal place to spend the time from May until September.

Dr. C. H. Edmondson presents the following preliminary report upon his extensive collection of Protozoa:

Preliminary Report by C. H. Edmondson.

From June 20 to July 20, 1906, it was my privilege to pursue a systematic study of the marine protozoa which inhabit the waters in the vicinity of the Biological Laboratory of the Carnegie Institution at the Tortugas. This region is very rich in fauna of the unicellular type. All classes and subclasses of protozoa are well represented, the habitats being quite varied and the natural conditions favorable for their existence.

It would be difficult to find a more favorable environment for certain forms of marine protozoa than that which is furnished by the moat which surrounds the ruins of Fort

Jefferson. The ooze at the bottom of the moat and the algæ and other plants of low order which thickly cover the wall below the water line are the habitats of many interesting species, Rhizopods and Flagellates being especially abundant.

Surface tows were frequently made in the vicinity of Loggerhead Key by means of which many pelagic forms such as Noctiluca and various species of Radiolaria were obtained in great numbers. Experience taught me, however, that these forms must be placed under the microscope as quickly as possible after being taken from the surface of the sea if one desires to study them in the active condition.

Naturally, in the latitude of the Tortugas, Foraminifera are perhaps more abundant than any other group of protozoa. The beach rocks of Loggerhead Key which are exposed at low tide are covered in many places by algæ, inclosed in the matted growth of which may be found myriads of beautifully sculptured, shell-bearing Foraminifera, including many species. The gulf-weed which floats at the surface of the sea carried with it a number of species, while not a few stalk-bearing forms were found attached to Sertularian hydroids which were borne by the gulf-weed. By means of the dredge with which the *Physalia* is fitted, some species, mostly Foraminifera, were obtained from a muddy bottom at a depth of about 20 fathoms, which were not found elsewhere.

In the five weeks' work over 90 species were studied and identified, besides several forms which are apparently undescribed and may represent new species. The species identified at the Tortugas are included in the following genera:

Acanthometra.	Cothurnia.	Lagena.	Peneroplis.
Acineta.	Cornuspira.	Lembus.	Peridinium.
Actinophrys.	Cympalophora.	Lichnophora.	Planorbulina.
Amphidinium.	Diophrys.	Lionotus.	Pleuronema.
Amphisa.	Discorbina.	Loxodes.	Polystomella.
Anisonema.	Dysteria.	Loxophyllum.	Spirillina.
Articulina.	Euplotes.	Mesodinium.	Spiroloculina.
Aspidisca.	Exuviælla.	Miliola.	Trachelocerca.
Astasia.	Frontonia.	Nassula.	Truncatulina.
Bolivina.	Glenodinium.	Noctiluca.	Uroleptus.
Bulimina.	Globigerina.	Nonionina.	Uronema.
Ceratium.	Gromia.	Orbiculina.	Uronychia.
Chilodon.	Gymnodinium.	Orbitolites.	Vertebralina.
Coleps.	Haplophragmium.	Orbulina.	Vorticella.
Collozoum.	Kerona.	Oxytricha.	
Condylostoma.	Lacrymaria.	Patellina.	

Prof. Edwin Linton presents the following report of his work upon the animal parasites of fishes and other animals:

Preliminary Report on Animal Parasites collected at Tortugas, Florida, June 30 to July 18, 1906, by Edwin Linton.

In the table on pages 114–115 will be found a list of the hosts which were examined for parasites, and a summary of the results of that examination, together with a few food notes. Where no food is recorded it is to be understood that either the alimentary canal was empty or the nature of its contents could not readily be identified.

While a more comprehensive search, extending over not only a greater range of species than is included in the foregoing list of hosts but also over a larger number of individuals under each species, is desirable, and would doubtless add very many species

of parasites, enough, I think, may be learned from the table to warrant the following general remarks on the helminth fauna of the Tortugas.

I shall record also in this connection a few extracts from notes made at the time the material was collected.

Acanthocephala.—Representatives of this order appear to be rare at the Tortugas. The species found in the frigate mackerel was *Echinorhynchus fristis,* which seems to be eminently a southern form, since it was found to be the most frequently recurring species at Beaufort, while a closely related species has a similar distribution in the fishes of Bermuda.

Neither in the fishes of Beaufort, Bermuda, nor Tortugas have I found Echinorhynchi as abundant as in the fishes of northern waters. There thus appears to be the same contrast between tropical and northern forms shown in the distribution of the Echinorhynchi as in many other groups of organic forms. In this case, however, there does not appear to be a multiplication of species along with relative paucity of individuals, a condition which is characteristic of many tropical forms.

Nematodes.—But few nematodes were found. Those found in the nurse shark, a species of Ascaris, were firmly attached to the stomach-wall, their heads penetrating at least as far as the muscular layer.

Representatives of the genus Heterakis were found sparingly in the green moray, gray snapper, spot, and hogfish. Some of those from the gray snapper and one from the spot agree closely with *H. foveolata.*

A species of Ichthyonema was found on three different dates in the ovaries of the gray snapper; one was also found in the gar.

Immature nematodes were found, usually encysted on the viscera, in the following fishes: Barracuda, yellow-grunt, yellow-tail, grouper, cabezote, French grunt, striped grunt, black grouper, yellow-finned grouper. In all cases the number of these immature nematodes was few. The most common type was characterized by having an elongated basal bulb on the esophagus, and a diverticulum from the anterior end of the intestine.

One very singular form was found in *Iridio kirshii,* which had a subglobular, chitinous pharynx which was marked with spiral ribs running from left to right anteriorly, thus crossing in optical section.

Cestodes.—The larval forms usually referred to by the name *Scolex polymorphus* are not so abundant as they would be in an equal list of northern fishes. Only a few were seen and only in the gray snapper, yellow-tail, grouper, and frigate mackerel.

Encysted stages, belonging for the most part to the genus Rhynchobothrium were found in eight of the species of fishes examined. *R. speciosum* was recognized in a number of instances. Encysted cestodes were found only on the viscera. No cases of flesh parasites comparable with that of the butter-fish (*Poronotus triacanthus*) of the northern coast, or of the hound-fish (*Tylosurus acus*) of Bermuda, were met. The selachians here as elsewhere are bearers of many species of adult cestodes, whose favorite place of lodgment is in the spiral valve.

I had the opportunity of examining but one sting-ray and that a small specimen. It yielded, however, a list of nine species of cestodes belonging to seven genera. This list, as identified at the time of collecting, is as follows: *Acanthobothrium paulum, Anthocephalum gracile, Phyllobothrium foliatum, Spongiobothrium variabile, Synbothrium filicalle,* and two species of Rhinebothrium and two species of Rhynchobothrium not yet identified. It may be inferred therefore that the sting-ray, if a sufficient number were to be examined, would yield as long a list of entozoa as it does at Beaufort or Woods Hole.

Some interest may attach to the fact that one lot of parasites is credited to the tiger-shark in the table, although the shark from which they were obtained was not identified.

LIST OF HOSTS EXAMINED FOR PARASITES AND SUMMARY OF RESULTS.

Host.	No. of hosts examined.	Acanthocephala.	Nematodes.	Cestoda.	Trematoda.	Ectozoa.	Food notes, etc.
Ginglymostoma cirratum (nurse-shark).	3 large, 3 small, on five different dates.	....	23, one species attached to wall of stomach.	8 species, represented by numerous to few individuals, in spiral valve.	....	One leech on tongue.	Small specimens with fish, crustacea, and annelids in the stomach; large specimen empty, except spine of sea catfish and fragment of nemertean.
Galeocerdo tigrinus (tiger-shark).	1 (9 feet)...........	....	....	3 sp., very numerous in spiral valve.	....	....	Stomach contained two tin cans, one bottle, one large shark hook with swivel, and numerous fragments of Palinurus.
Carcharhinus platyodon (cub-shark).	1 (10 feet)..........	....	....	5 sp., few in spiral valve.	....	....	Lenses of fish eyes in intestine.
Dasyatis say (southern sting-ray).	1 (18 in. broad)..	....	....	9 sp., few in spiral valve.	....	2 isopods..........	Crabs in stomach.
Lycodontis moringa (spotted moray).	1 (2 feet)...........	....	....	....	1 sp., few in stomach.	....	
Lycodontis funebris (black moray).	1 (4 feet)	....	1, in rectum......	1 encysted on rectum.	3 sp., numerous in stomach and intestine.	....	A spotted moray was ejected from the stomach. It had probably been swallowed after entering the trap.
Clupanodon pseudo-hispanicus (Spanish sardine).	33 on two dates..	....	Immature, very small, encapsuled, few.	1 encysted on viscera.	2 sp., few..........	2 copepods.........	Small annelids.
Tylosurus marinus (garfish)...	1 (18 in.)...........	....	....	....	2.....	....	Stomach empty, fish caught with fish bait.
Atherina laticeps (cabezote)...	33 on two dates..	....	....	Larval forms encysted on viscera, few.	....	Isopods, from mouth, few.	
Auxis thazard (frigate mackerel).	1.......................	8..............	....	Larvæ, few........	2 sp., few.	....	
Epinephelus striatus (grouper).	9 on five dates...	....	Few, immature.	3 sp., larval and encysted.	2 sp., few..........	....	Fish and crabs.
Mycteroperca venenosa (yellow-finned grouper).	1.......................	....	2, encapsuled....	Many cysts on viscera.	....	2 isopods on gills.	Fish.
Mycteroperca bonaci (black grouper).	1.........	....	Few, immature.	4 sp., encysted and larval.	1 sp., numerous.	....	

Neomænis griseus (gray snapper).	41 on six dates	1	3 sp., few	2 sp., larval and encysted.	4 sp., numerous.		Fish (Atherina), crabs, isopods, spines of sea-urchins.
Ocyurus chrysurus (yellow-tail).	3		Few, immature.	Few, larval.	1		
Hæmulon macrostomum (striped grunt, "porgy").	2 on different dates.		3, immature		2 sp., few		Annelids.
Hæmulon sciurus (yellow grunt).	35 on six dates		Few, immature.		8 sp., mostly represented by few individuals.		Crustacea and annelids.
Hæmulon flavolineatum (French grunt).	1		1, immature				
Leiostomus xanthurus (spot).	6 on three dates.		2 sp., one adult, few of each.		1		Fish and algæ.
Abudefduf saxatilis (cow-pilot).	1				1		
Lachnolaimus maximus (hogfish).	1		1		1		Broken mollusk shells and fragments of crustacea.
Iridio kirschii	1		2 fragments				
Chætodipterus faber (spade-fish).	1				4 sp., one very numerous.		The very long intestine was filled with material browsed from the reef, mainly gorgonia and sponges.
Angelichthys isabelita (angel-fish).	1				3 sp., few		Alimentary canal filled with gorgonia, sponges, etc.
Sphyræna barracuda (great barracuda).	3 large, 4 small.		1 sp., immature, few.		1 sp., few		Fish in stomach of large specimens.
Thalassochelys caretta (loggerhead turtle).	1				2 sp., one of them represented 1 specimen, the other by over 3,000.		
Shrimp—common, on gulf-weed.	12 on three dates.					Isopod, near Phryxus, found on most of the shrimp.	

On June 2, before my arrival at the laboratory, a 9-foot shark was captured. Its spiral valve was opened and placed in 5 per cent formaldehyde. Upon examining this material I decided that it had come from a tiger-shark. As this is an unusual method of identifying a fish it may be worth while to record my reasons for having confidence in this identification. In the first place, the valve itself is of the same type as that of the tiger-shark. This fact, however, does not exclude the cub-shark, which is common in these waters. In the second place, the varied contents of the stomach (see table) agree with what has been recorded for this species (U. S. Fish Commission Bulletin for 1899, pp. 270, 271, 425).

Again, there were a large number of both adult and young and free ripe joints of the singular cestode *Thysanocephalum crispum*. In all the tiger-sharks which I have examined in the Woods Hole region I have found this parasite abundant and varying from young specimens a few millimeters in length to adults with ripe segments and measuring as much as a meter in length. There were also large numbers of ripe proglottides free in the chyle of the intestines. Furthermore, I have never seen this cestode, in its adult stage, in any other host than the tiger-shark.

Since tiger-sharks are rather common in the waters about the Tortugas this vicarious identification is probably correct.

In like manner the finding of the cestode *Discocephalum pileatum* in the cub-shark, while probably not justifying a change in any record of habitat, at least calls in question the validity of a former identification.

This species was based on four specimens obtained from material brought to the laboratory of the United States Fish Commission at Woods Hole, Massachusetts, July 19, 1886, and taken from what was reported to me to be a dusky shark (*Carcharhinus obscurus*). The viscera only were brought to the laboratory. *C. obscurus* is common in the waters about Woods Hole, but *C. platyodon* has not been recorded from any point so far north.

The following reasons are given for thinking that the host of the type specimens of *D. fileatum* may not have been *C. obscurus.*

The first and only find of this species at Woods Hole was the one upon which the genus and species were founded. No other entozoa were found associated with them. In all other specimens of dusky shark which I have examined at Woods Hole I have found numerous cestode parasites. As a rule there were several different species, usually represented by numerous examples, in each shark. The same conditions were found to prevail in the dusky sharks which I examined in 1901 and 1902 at Beaufort, North Carolina.

The second find of *D. pileatum* was made in 1903 when I collected seven specimens from a cub-shark (*C. platyodon*) in Bermuda. In that case also the worms were not associated with any other cestodes, and the heads, as in the first instance, were firmly attached to the walls of the intestine. These conditions were repeated very closely in the cub-shark which was examined at Tortugas. The single specimen of *D. pileatum* was firmly attached to the intestinal wall, the disk-like head being embedded in the submucosa. There were, however, associated with this specimen, five other minute cestodes, representing four species and as many genera. They were *Anthobothrium laciniatum, Phoreibothrium lasium, Otobothrium crenacolle,* and another which was not identified at the time of collecting and concerning whose systematic position I am not yet certain.

Leaving the species *D. pileatum* out of the account, it will be observed that two of the above species, viz, *A. laciniatum* and *P. lasium,* have been found in the dusky shark, both at Woods Hole and at Beaufort, and one other (*O. crenacolle*) at the latter place. While there is hence established a close resemblance between the cestode parasites of *C. obscurus* and *C. platyodon,* I am still of the opinion from the data thus far at hand that some doubt must rest on the dusky shark's being a host of *D. pileatum.*

Trematodes.—Beyond the preliminary examination made at the time of collecting, and often of necessity hastily given, the collection has not been studied.

From notes made during the preliminary examination it would appear that there are about 33 species, many of which are new. Of these, all but nine could be referred to the old genus Distomum. Three species of Gasteristomum were noted. Appendiculate distomes were seen in but two instances, one in the green moray and the other in the Spanish sardine. Those from the moray were numerous and resembled the form which I have been recording under the name *D. monticellii;* those from the sardine were few and agree with *D. appendiculatum.*

Many of the species are represented in the collection by but one or at most few specimens, and it may be advisable to refrain from giving them names until more material is secured.

A distome, probably represented by more than one species, found in most of the lots of gray snappers, grunts, and groupers, is unique in that the ova, as they lie in the folds of the uterus, present a wreath-like appearance, and each ovum has a long, slender filament, such as is common on the ova of monogenetic trematodes.

Trematodes were found in large numbers in only two instances, a spade-fish, examined July 18, and a loggerhead turtle, examined July 1.

In general it may be said that the trematode fauna of Tortugas is rich in species.

Ectozon.—Parasitic Isopods were found on the sting-ray, cabezote, yellow-finned grouper, and a small shrimp common in the gulf-weed.

Parasitic Copepods were found on only one fish, the Spanish sardine.

One leech, colored vivid green and red-brown with blotches of white, was found on the tongue of a nurse-shark.

General Observations.—The groupers of the Tortugas like those of Bermuda, especially the older specimens, are characterized by having more or less abundant cysts on the viscera and often in the walls of the stomach and intestine. These cysts are, as a rule, dark brown, often nearly black. The color is due to the abundant pigment which is deposited in the cyst. While these cysts are more often than otherwise due to cestodes, accumulations of pigment and degenerate connective tissue were also found associated with other entozoa, viz, nematodes and acanthocephala in Bermuda, and nematodes in Tortugas.

It is perhaps worthy of remark that the great barracuda, which is a very voracious and predatory fish, appears to harbor but few parasites, either as a final or intermediate host. This conclusion is warranted also from the results of the examination of 5 barracuda in Bermuda in 1903. The largest Tortugas specimen measured about 1.5 meters in length; the Bermuda specimens were about one-half that length.

It would be of interest to know whether the apparent immunity from parasites of the barracuda and other fish is correlated in any way with the digestive ferments.

Dr. Charles Zeleny carried out an extensive series of observations upon regeneration, in order to determine the effect of successive injuries upon the rate and character of regeneration in Crustacea. He also studied regeneration in Cassiopea, and found that except in cases where all or nearly all of the arms are removed there is an increase in the rate of regeneration of each arm coordinate with an increase in the number of removed arms. This confirms Zeleny's law that the animal with the greater number of removed parts regenerates each and every part at a more rapid rate than does the animal with the lesser number of removed parts. Dr. Zeleny is now at work upon his observations, and hopes soon to publish an account of his results.

Alfred G. Mayer studied rhythmical pulsation in the medusa *Cassiopea,* the branchial arms of the stalked barnacle *Lepas,* the heart of *Salpa democratica,* and of the embryo loggerhead turtle. More than 1,000 experiments were carried out. It appears that the stimulus which produces rhythmical pulsations in *Cassiopea* is conducted by the diffuse nervous network or epithelium of the subumbrella, not directly by the muscles themselves. Pieces of subumbrella tissue cut so as to form a complete circuit can be set into sustained pulsation. The waves of pulsation may cross, or trend with, the muscle fibers and pulsation will be sustained provided the circuit be unbroken. Any cut which breaks the circuit instantly interrupts the pulsation and sustained pulsation can not be restarted. This sort of pulsation is maintained by a single originally stimulated point, and whenever the contraction waves return through the circuit to this point they are restimulated and again sent forth through the circuit.

It is the general rôle of magnesium to inhibit or restrain pulsation, while sodium chloride, potassium, and calcium unite to form a powerful stimulant producing abnormally energetic, but not long-sustained, pulsation. It is the office of magnesium to restrain this powerful stimulant, and thus to prolong its action indefinitely. Thus a Ringer's solution is only a stimulant; and a certain amount of magnesium is necessary in order to restrain and at the same time permanently sustain pulsation.

The Atlantic palolo worm (*Eunice fucata*) swarmed on the mornings of July 11 and 12, and the last quarter of the moon fell on July 13, 1906. Experiments to determine the nature of the reaction which causes the swarm were unsuccessful, but will be repeated under better conditions. We now know that the worm may swarm when there is no rise and fall of tide.

About 150 colored drawings were made of new or rare Siphonophoræ, Ctenophoræ, and Medusæ.

On July 24, 1906, the *Physalia, Sea Horse,* and other Department vessels were safely laid up in the Miami River, and the yacht's license was surrendered to the custom house.

I take pleasure in reporting that the property intrusted to my care is in good condition.

BOTANICAL RESEARCH.

DEPARTMENT OF BOTANICAL RESEARCH, TUCSON, ARIZONA.*

BY D. T. MACDOUGAL, DIRECTOR.

Upon the organization of the Department at the beginning of the present year, attention was turned to the extension and development of the investigation of problems which might be attacked to greatest advantage in connection with the Desert Botanical Laboratory at Tucson, Arizona. The Desert Laboratory was established in 1903, and in the period of two years during which its facilities were actually available its effectiveness was amply demonstrated by the results secured by the resident investigator and visiting naturalists. Additional facilities and equipment have been provided as described below, and the staff has been enlarged to include workers on some of the more important questions in the physiology of plant life.

In this expansion an attempt was made to secure a correlation of effort, not only among the members of the Laboratory staff, but also to include the work of other scientists receiving subsidies from the Institution. Beyond this it was taken as a matter of course that the researches taken up should not duplicate the activities of other institutions any farther than might be necessary and justifiable by the peculiar local conditions offered by the region in which the Laboratory is located.

As a natural outcome of the principles noted above, questions arise which require the more or less combined and organized effort of the entire Laboratory extending over a term of years, with participation on the part of the entire staff at various times. Work of this character demands the utmost exactness in making records of observations and experimental results, as well as definiteness of methods, in order to be of a value commensurate with the effort expended.

THE VEGETATION OF THE SALTON BASIN.

It seems to be fairly apparent that the greater portion of the more pronounced arid areas in North America has been in submersion during comparatively recent geological periods, and consequently that the highly specialized flora which now inhabits such regions is of fairly recent origin. In seeking to interpret the striking adaptations which are so profusely exemplified in the desert flora and in securing evidence upon problems of the physiology of plant life, it would appear that anything that would give suggestions as to the movements and behavior of such plants in the occupation of new areas might be of great value. The Salton Basin in southern California offers opportunities of this character.

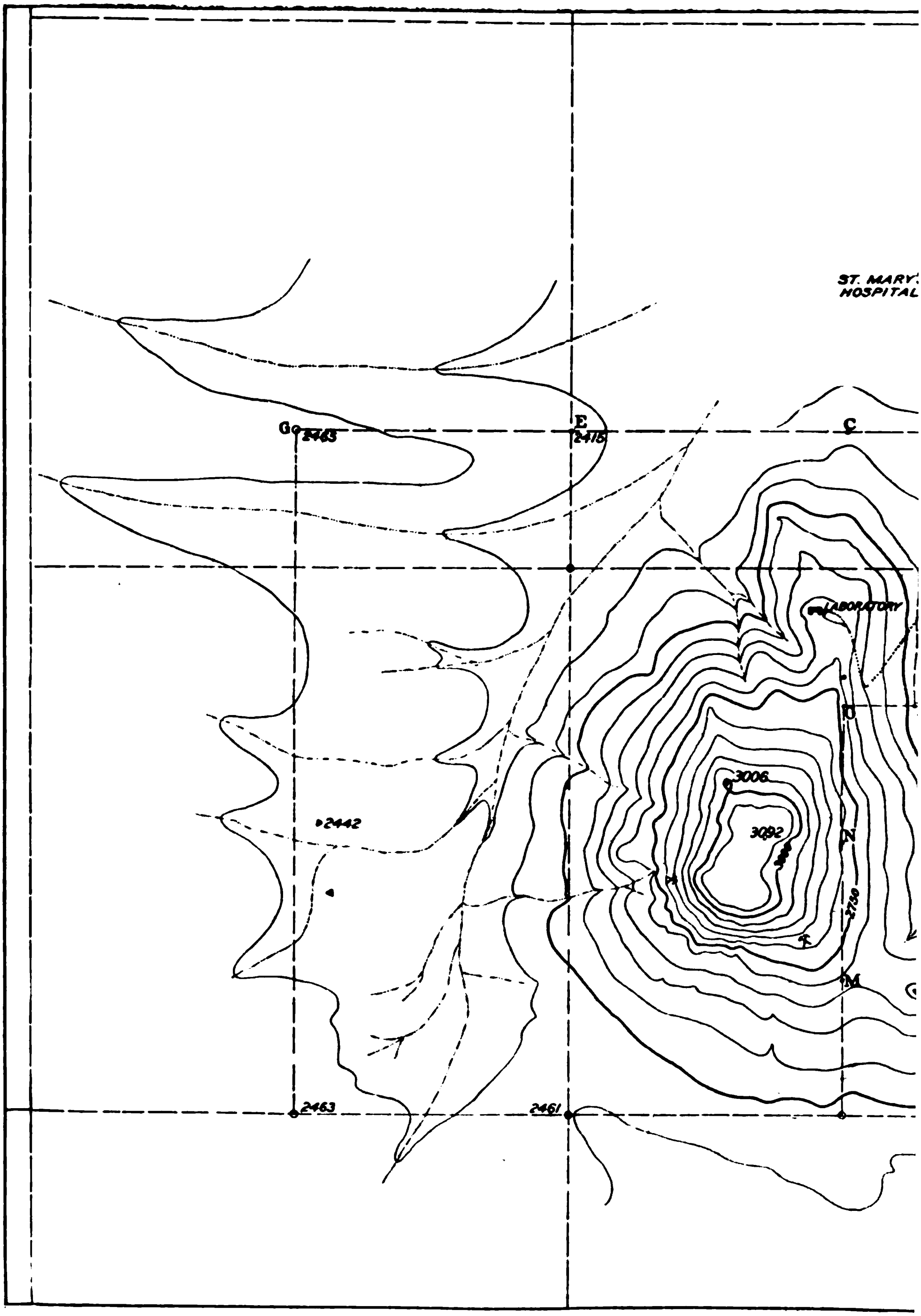
* Report for the year ending September 30, 1906. Grant No. 309. $33,000 for investigations and maintenance. (For previous reports see Year Book No. 2, p. XXVI, Year Book No. 3, pp. 98-100, Year Book No. 4, pp. 126-127.)

The Salton Basin is an irregular oblong depression, with an area of 2,000 square miles, having its long axis lying northwest and southeast, extending from the angle formed by the San Jacinto Mountains and San Bernardino foothills in California to a point across the international boundary line between the United States and Mexico, being cut off from the Gulf of California by the alluvial deposits in the delta of the Colorado River. The lowest portion of this depression is 287 feet below sea-level, and the presence of an old beach line 22 feet above sea-level shows that comparatively recently it has been the site of a lake, which emptied southwardly into the Gulf of California. Within historic times, however, the basin has been empty, and this great bowl is one of the marked features of the Colorado Desert. The rainfall is exceedingly scanty and the soil is highly charged with salts of various kinds, consequently the vegetation is of a pronounced spinose or halophytic type.

Several times within the last century the flood waters of the Rio Colorado have been diverted to such an extent as to flow into the basin and form a small lake, and the presence of several minor beach lines on the slopes of the basin suggests that such inflows have taken place many times within the last few thousand years, and also that the level of the ancient lake was not lowered uniformly.

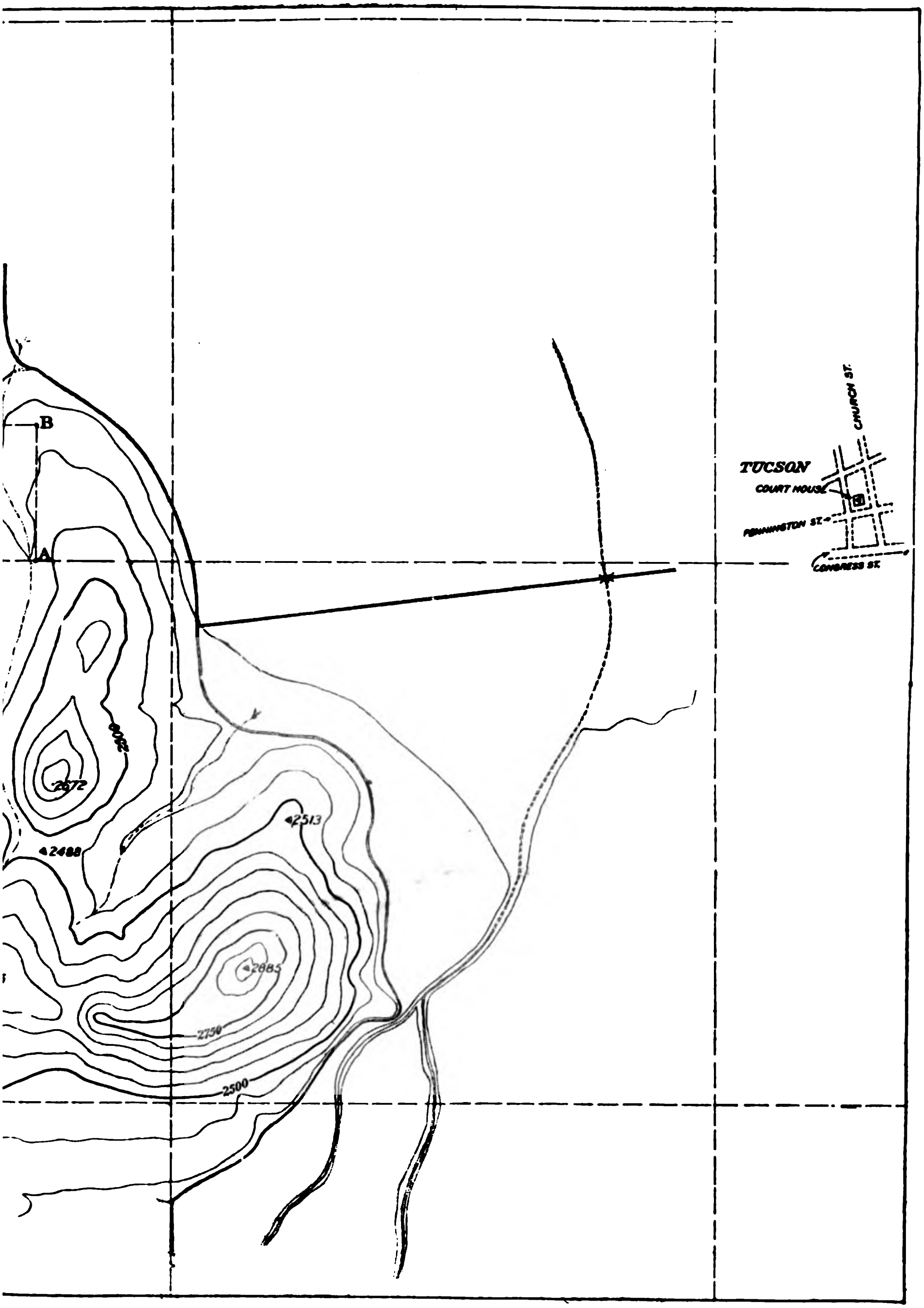
During the last three years some faulty engineering operations have opened a channel leading into the basin, with the result that the main flow of the Colorado River has run into the depression for the greater part of the last year, forming a lake with an area of nealy 500 square miles, accompanied, of course, by the entire destruction of the desert flora on the submerged lands. As a result of the engineering efforts of the Southern Pacific Railway the channel leading from the main course of the river to the Basin was closed early in October. The gradual shrinkage of the lake may now confidently be expected, and the desert vegetation will probably reoccupy the areas left bare by the recession of the water. As a fortunate prelude or beginning of this study, Dr. D. T. MacDougal and Mr. Frederick V. Coville visited the basin in 1903 and made some observations upon the vegetation, together with some photographs of the manner of occurrence and habit. The evaporation and seepage in the region are such that seven or eight years will be necessary to empty the basin, which will thus afford experimental conditions on a large scale of the re-vegetation by xerophytic plants of a submerged area. A similar depression on the western side of the Cucopa Mountains, in Baja California, is expected to offer corroborative evidence, while the altered conditions offered by the diversion of the water in the delta lands will yield results of great value as to distribution.

An examination of the effect of the advancing water line upon the vegetation of the contiguous desert was made by Dr. D. T. MacDougal and Mr.



RESERVATION AND VICINITY OF THE DESERT

PLATE 8.



)TANICAL LABORATORY OF TUCSON, ARIZONA

Godfrey Sykes in the spring and summer, and Prof. and Mrs. V. M. Spalding also began some observations near the shore at Mecca, California, early in October, at the maximum height of the water.

INFLUENCE OF ALTITUDE AND CLIMATIC FACTORS UPON VEGETATION: ACCLIMATIZATION.

As a result of the activities of horticulturists and botanical gardens a large number of species have been transferred from one country to another, and some observations as to alterations in habit and form are recorded, resulting from such removals. A few experimental tests have been made in the cultivation of species through a range of altitudes, and some of the morphological changes induced have been described. It is known that the color, time of bloom, habit, structure of the root and shoot, general aspect of plants, and economic value may be greatly altered by cultures at various altitudes, but no systematic tests have been made to determine to what factors in the climates concerned these differences are due. The solution of the problems involved would settle some of the most important problems in general physiology, and would also go far in enabling us to account for the structure and form of the species of which the vegetation of the earth is composed.

It is by means of experimental observations of this kind that it also may be hoped to obtain evidence as to the inheritance of acquired characters, a question which has been a much vexed one for many years. No adequate tests have yet been made to ascertain whether or not the marked changes induced in plants by cultivations at higher or lower altitudes than the normal are fully transmissible to succeeding generations grown under other conditions.

The practical problems of acclimatization offer some highly peculiar conditions. Thus two separated localities may offer meteorological conditions apparently similar, so far as ordinary methods of weather records show, yet the exchange of plants between the two places will be attended with but indifferent success, even when differences in composition of the soil are accounted for. It seems unnecessary to point out that when the factors in climate have been accurately analyzed as to their effect upon vegetation a much more rational basis will be afforded for efforts at acclimatization.

The entire plan for investigations in connection with the above entails the establishment of small plantations, each embracing a fraction of an acre at an elevation of 2,300 feet in the alluvial valley of the Santa Cruz River, at the well-site of the Desert Laboratory, near Tucson; at the Laboratory, in an arid situation, with a rainfall averaging 12 inches; at Castle Rock, a spur of the Santa Catalina Mountains, with a limited rainfall, upon which observations are being taken, and at an elevation of 8,000 feet, near the summit of the Santa Catalina Mountains, in a locality where the rainfall is probably greater than the possible evaporation. Steps are being taken to secure thermometric data in all of the localities, and to otherwise ascertain the cli-

matic factors to be dealt with. In addition to the above, Dr. G. E. Hale, director of the Solar Observatory on Mount Wilson, near Pasadena, in southern California, has placed at the disposal of the Desert Laboratory facilities by which a plantation may be established on the summit, at an elevation of 5,500 feet, in a climate quite different from that offered by any of the above localities. A comparative culture has also been established at the tropical station at Cinchona, Jamaica, in which a few species are under observation. The completion of the plan entails the establishment of a culture at 11,000–12,000 feet in the San Francisco Mountains, in northern Arizona.

As an illustration of the method of experimentation the following plants have been taken from the desert locality of the Desert Laboratory at 2,300 feet, to the austral plantation on Castle Rock, at an elevation of 6,000 feet.

Sphæralcea pedata, roots and seeds, perennial.
Jasmine gracilis, stocks, perennial.
Krameria canescens, stocks, perennial.
Bigelovia hartwegii, clumps, perennial.
Menodora scabra, stocks, perennial.
Hilaria mutica, roots and seeds, perennial.
Cassia covesii, stocks, perennial.
Encelia farinosa, stocks and seeds, perennial.
Verbena ciliata, stocks and seeds, perennial.
Covillea tridentata, seeds, perennial.
Franseria deltoidea, seeds, perennial.
Plantago aristata, seeds, annual.
Plantago fastigiata, seeds, annual.
Lesquerella gordonii, seeds, annual.
Daucus pusillus, seeds, annual.
Harpagonella palmeri, seeds, annual.
Xanthium canadense, seeds, annual.

The following species from near sea-level, in a moist climate, were placed in a culture in the alpine station on the Santa Catalina Mountains, at an elevation of 8,000 feet:

Phytolacca decandra, roots, perennial.
Polygonatum biflorum, rhizomes, perennial.
Antennaria biflorum, rhizomes, perennial.
Antennaria neglecta, rhizomes, perennial.
Aquilegia canadensis, rhizomes, perennial.
Bicuculla cucullata, bulbs, perennial.
Selaginella rupestris, rhizomes, perennial.
Hepatica hepatica, roots, perennial.
Arisæma triphyllum, corms, perennial.
Sequoia gigantea, seeds, perennial, from California.
Roripa americana, roots, perennial, Lake Champlain.
Quercus, a dwarf species from the Sierra de Pachuca, Mexico.
Sanguisorba canadensis, roots, perennial.
Geum canadensis, roots, perennial.
Aletris farinosa, roots, perennial.
Lilium superbum, bulbs, perennial.
Trillium undulatum, rhizomes, perennial.

Roripa americana, the American water-cress, which Dr. MacDougal secured from its habitat in Lake Champlain in 3 feet of water, in 1902, was transferred to ordinary soil cultures in 1902, in which it has since grown, having undergone the most sweeping changes in structure and habit, some cultures of this plant being carried on at Cinchona, Jamaica, in a tropical climate, and, as noted above, it has been placed in three of the plantations in connection with the Desert Laboratory. Several years must elapse in the

course of such experiments before definite results may be expected; but with this species the progress of four years is already available, and it may be expected to furnish data of importance within a short time.

The Movements and Distribution of Desert Vegetation, by Prof. V. M. Spalding.—During the past year a comprehensive ecological study of the plant associations and their habitats on the reservation of the Desert Botanical Laboratory and adjacent territory has been undertaken. This study has been greatly facilitated by a topographical survey, which has been completed, and a geological survey, now in progress, under the direction of the geological department of the University of Arizona. It is based, primarily, upon determinations of habital factors by several members of the staff of the Desert Laboratory, and upon definite observations and records of the occurrence, habits, structure, and physiological activities of characteristic plants of this district. Twelve well-defined habitats, each with its own association of plants, have been studied, and, at the several stations located for this purpose, some progress has been made in an attempt to correlate plant behavior with known factors of environment, particularly as regards relation to water supply, alkalinity of soil, exposure, and drainage. Curves have been constructed showing relative frequency of some of the most characteristic species of typical localities. Areas of uniform size have been permanently located, and their vegetation charted and photographed. The invasion of a number of species has been watched and their present position indicated on charts. By these and other means data are accumulating for a rational study of competition, succession, and adaptation as they are exhibited in this region. An analysis of the flora has been made and certain relations to floras of other regions established, thus preparing for a more comprehensive study of historical factors than has hitherto been made in this territory. Up to this time only limited districts in southern Arizona and New Mexico have been worked over critically, but preparations are being made for the necessary extension of the area in which comparative observations are carried on.

Seasonal and Other Variations in Volume of Succulents, by Mrs. E. S. Spalding.—Measurements of the bodies of several succulents in which the water-storage function is well developed have been continued from last year, and a great amount of well-authenticated data showing rapid and relative great alterations has been obtained. Evidence has been accumulated that the changes in the shape and volume of the saguaro (*Cereus giganteus*) are controlled not only by its water content but in a minor degree by temperature and illumination. It is hoped to continue these measurements and determine the parts played by the separate factors, and at the same time differentiate the changes in question from growth accretions. Measurements have also been taken of a number of individuals of bisnaga (*Echinocactus*) and of *Opuntia engelmannii.*

Topographical and Geological Survey of the Laboratory Tract, by Prof. C. F. Tolman.—In the investigation of the movements and distribution of desert vegetation by Professor Spalding it was found necessary to secure a map of the tract on which experiments are being carried out, and this was undertaken by Professor Tolman, assisted by some of his students from the University of Arizona.

Studies in Transpiration, by Dr. B. E. Livingston.—During the year the investigation of the relations of plants to soil, moisture conditions of the soil, and air, described in the Year Book for 1905 (4, p. 128), have been repeated as to certain details to obtain confirmatory evidence while reading proof of the completed paper upon the subject which has appeared as Publication No. 50 of the Institution.

Dr. Livingston's researches have the ultimate purpose of determining in a comprehensive way the entire water-relations of desert vegetation. In this work it is of the greatest importance to secure a continuous record of the evaporation of water from some adopted standard of surface, and an evaporimeter, the initial design of which was made in 1905, has been developed until now a complete and continuous tracing may be obtained which will be of the greatest importance in researches of many kinds in progress at the Desert Laboratory.

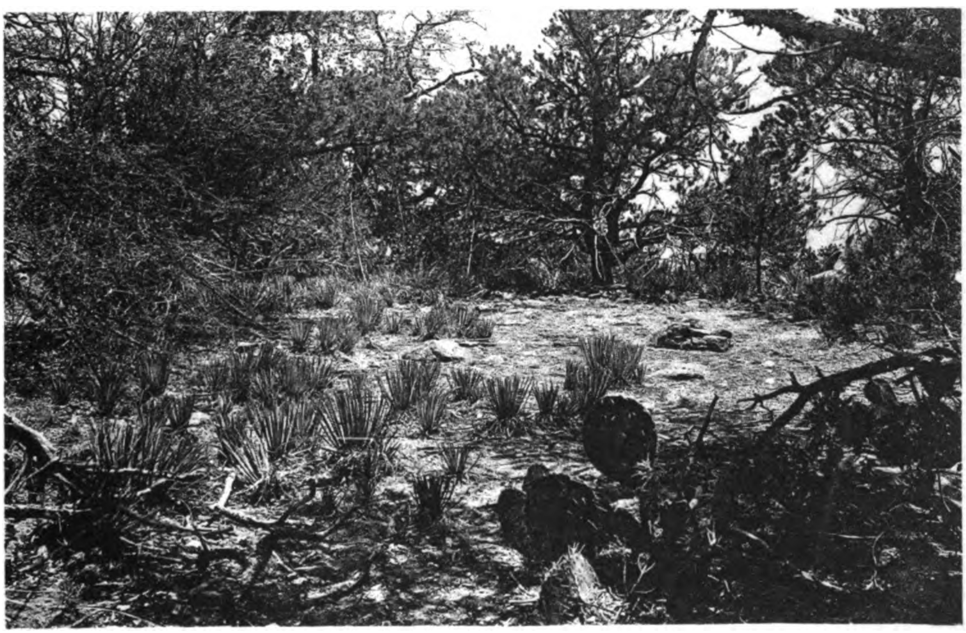
In the further unification of results it becomes necessary to ascertain to what extent the available records of transpiration obtained from separated branches are comparable with those obtained from entire plants under fairly normal conditions. The accomplishment of this result will do much to standardize results and reduce much apparent incongruity as to existing conclusions.

The study of the rate of transpiration displayed by various species shows that much difference exists among separate forms as to the physiological regulation of transpiration. The detection of these differences becomes possible by the use of the curves obtained from the recording evaporimeter noted above. It is proposed to extend these observations to include representatives of the more prominent types of xerophytic and other vegetation.

Annotated Bibliography of Literature Relating to Evaporation, by Mrs. Grace J. Livingston.—The fragmentary condition of the literature on evaporation rendered a bibliography of the subject necessary before much advance could be made in a comparative study of the subject, or a development of new methods, and the results at hand now include nearly seven hundred legitimate titles.

Physiology of Stomata, by Prof. F. E. Lloyd.—The experiments of the previous summer (1905) have been repeated, as have also the observations on the normal behavior of stomata and the changes in the content of the guard

VIEW OF DESERT LABORATORY FROM WEST.



SITE OF AUSTRAL PLANTATION ON CATHEDRAL ROCK,
SANTA CATALINA MOUNTAINS.

cells (described in the previous report), and confirmatory results have been obtained. In addition to the earlier experiments on the effect of darkness and air deprived of carbon dioxid, others have been done on the effect of the different parts of the spectrum, from which the following briefly summarized conclusions have been derived.

In all parts of the spectrum the movements of stomata are the same qualitatively, such quantitative differences as have been observed being easily and properly explained on the grounds of general starvation. This is apparent from the fact that in the blue-violet end of the spectrum the amplitude of movement grows gradually less after the third day, as compared with the amplitude of movement in the red end of the spectrum. In view of the persistence of starch in the stomata under both these conditions, and in view of other contributory evidence, it appears clear that the food content of the guard cells is derived, in large part at least, from the adjacent chlorenchyma, and upon the continual starvation of this latter, the effect is to make it impossible for the stomata at length to obtain material from which energy may be obtained. Little if any movement occurs in the darkness, and a persistent exposure to this condition results in the starvation of the guard cells, but not for three or more days. In general the data obtained are in confirmation of the truth of the theory first suggested by Kohl, that the phenomena of stomatal action are explicable only by an understanding of the behavior of the enzymes resident in the guard cells, for which theory, however, Kohl failed to offer convincing evidence.

Experiments have also been done to test the theory of induced rhythm as applied to stomatal action. Evidence had been previously obtained in 1905 that such rhythm occurs in transpiration. Francis Darwin had also held this view for stomatal action, but experiments of the same general character as those of Darwin done on the Virginia creeper (*Ampelopsis quinquefolia*) are distinctly inconclusive if not inimical to Darwin's view. Also on the matter of stomatal action during wilting, during which Darwin holds there occurs a preliminary opening, the data as recently obtained are unequivocal, showing that a continual closure, concomitant with, and due to, wilting, occurs.

Topography of Chlorophyll-masses, by Dr. W. A. Cannon.—The highly adaptive relations sustained by desert plants to light and humidity as evidenced by the aspect and structure of their shoots necessitates concomitant modifications of the disposition of the tissues bearing chlorophyll, which is usually present in large quantity in xerophytic forms. When the species bears only the rudimentary leaves, or none at all, the chlorophyll in twigs, branches, and stem is particularly well marked. Certain desert trees, as *Parkinsonia microphylla* and the other species of this genus, owe their characteristic color almost wholly to the chlorophyll present in the cortex of

the branches. There appears to be a constant correlation between the foliar habit of the desert plant and the character of the cortical chlorenchyma. For example, in forms with rudimentary leaves, or with none, as *Krameria canescens, Aster* sp., *Koeberlinia spinosa,* the cortical chlorenchyma of the branches is palisaded; but in leafy plants the chlorenchyma is composed of cuboidal cells. Also in plants in which the leaves are rudimentary, the palisade of the branches is very like that of the rudimentary leaves of the same plant. As regards the distribution of the chlorophyll in the branches it was observed in pith, medullary rays, in wood parenchyma and in parenchyma of cortex, and it occurs in the secondary cortex of older stems. Chlorophyll was noted in the pith of stems of so great diameter as 3 cm.

The persistence of the chlorophyll so deeply in the branches may be associated with the great intensity of light in the desert which tests on the refraction of light from the plant surface indicate is absorbed by the plants in remarkably high percentages. The recession of the chlorophyll, which occurs nearly *pari passu* with the increase in diameter of the stem, takes place centrifugally. To this there is the single exception of the lingering of the chlorophyll in wood-parenchyma in the neighborhood of the larger ducts after that in the adjacent medullary rays has disappeared.

Root-habits, by Dr. W. A. Cannon.—A survey has been begun which is meant to include the principal types of desert vegetation with a view to bringing to light information concerning the general form and habit of the root-systems of desert plants and determine in what manner the peculiar conditions of absorption, and the requirements of anchorage are met. Seedlings as well as mature individuals are examined by means of methods of sluicing which allows the examination of the finest ramifications *in situ.* One of the interesting discoveries resulting from this work is the fact that such seedlings as those of some opuntias develop storage organs in the roots which function for the accumulation of a reserve water supply until the succulent stems reach a size when they may hold a comparatively large amount. Then the embryonic root storage organs atrophy.

Soil and Air Temperatures.—The differences between the temperature of the soil in which the absorbing organs of a plant are functionating and of the air into which transpiration is taking place form an important element in many of the primary physiological processes, and the results of the earlier studies upon the subject seemed to warrant a continuation of this work. To this end a series of recording apparatus is installed at the Desert Laboratory, a second at the New York Botanical Garden, while data extending over several months were obtained at Cinchona, Jamaica, during 1905 and 1906. A comparison of the results reveals many differences yet to be explained.

Origin, Distribution, and Physiographic Development of the Flora of the Everglades, by Dr. H. C. Cowles.—Dr. Cowles had previously made one visit

to the Everglades, the results of which have appeared in print; the investigation was taken up anew October 1, and it is not possible to present the advanced results obtained at this time.

Morphology and Physiology of Storage Organs, by Dr. D. T. MacDougal.—A comprehensive examination of the water-storing functions in plants of arid regions has been begun in which the physiological as well as the morphological aspect of the subject is taken into consideration. The adaptations for accumulating and holding a reserve supply of water occur in all parts of the root and shoot of various species of seed-plants, and the development of tissues for this function shows some important morphological features. So far as a general survey of American deserts has been made it seems justifiable to conclude that storage organs and storage plants are most abundant in regions in which the scant rainfall comes within a limited period in the year, while the remainder of the year is lacking in sensible precipitation. In regions such as those on the lee side of the main range of the peninsula of Baja California, in which the precipitation is very slight, at any time, and in which the total is small, very few plants are found with well-developed storage organs.

Ibervillea sonoræ ("guarequi"), one of the cucurbits, develops a storage organ at the base of the stem, the size of squash, which is furnished with a heavy outer covering highly resistant to evaporation. During the dry season these structures lie on the surface of the hot sands unaffected. With the beginning of the rainy season roots are quickly formed, shoots are sent up, and fruit and seed quickly matured, when the thin stems die away and the guarequi goes into a resting condition for another year. Some of these plants were collected and placed on a dry shelf in a museum case in February, 1902, where they have since remained. Every year since, at a time corresponding to the rainy season in the native habitat, thin stems have been sent up, which after a time die back after having developed leaves. Five years' growth has thus been made at the expense of water stored up in October, 1901, and the great storage organs are still sound and give evidence that they may furnish supplies for the annual formation of stems and leaves for a decade. A large number of species from the desert show similar adaptations.

Explorations and Field Work, by Dr. D. T. MacDougal.—The original sketch of some of the better known deserts of North America made by Dr. MacDougal and Mr. Coville has proved so useful in the organization of researches and has afforded so much information that it has been deemed advisable to extend the work to include areas not previously examined. In accordance with this plan a visit was made to the sage-brush deserts of northern Nevada, to the arid and saline areas contiguous to Great Salt Lake in Utah, and to the great bolson of Las Vegas, in southern Nevada, all of

which lie in a zone in which the annual precipitation does not exceed ten inches. The vegetation is composed chiefly of compositaceous types with reduced surfaces fitted for conserving rather than storing moisture and of chenopodiaceous forms, such as are characteristic of regions with soils highly charged with salts.

The latter part of August and the month of September were spent in making an examination of the desert conditions, and the general aspect of the vegetation near Laredo, Texas; Saltillo, Mexico City, and in the region southward from Tehuacan to Mitla, in latitude 17° N. By the cooperation of Dr. J. N. Rose, assistant curator of botany in the Smithsonian Institution, detailed studies were made which would have been impossible without its aid. The Tehuacan desert was found to constitute a type not hitherto examined, and to be extremely rich in plants with adaptations for the storage of water. Among these are the numerous massive cacti, several genera of which are represented by species that surpass the saguaro of Arizona in bulk. Three species of *Beaucarnea* were encountered in which the storage function is highly developed, and one of these, *Beaucarnea œdipus*, probably has a capacity for holding as much as a ton, or even a ton and a half, of water in reserve for its needs during dry periods. Much valuable living material was secured and sent to the Desert Laboratory for experimental purposes, and a carload of succulents was shipped to New York to be used by Drs. Britton and Rose in their investigations of the Cactaceæ.

Numerous expeditions, participated in by the various members of the staff of the Desert Laboratory, have been made to the Santa Catalina Mountains, the Sierritas, Quijotoa, and Tucson Mountains, and to several areas within a radius of 100 miles from the Laboratory. These trips are always organized for some special purpose, such as securing material for experimentation, or the examination of the structure or distribution of desert forms. Many of them have been shared by visiting naturalists.

Physiology of Genetics, by Dr. D. T. MacDougal.—In continuance of some investigations begun at the New York Botanical Garden in 1902 a series of cultures has been carried in the New York Botanical Garden by the courtesy of Dr. N. L. Britton, director, in which the assistance of Miss A. A. Knox has been obtained. The series of mutants or individuals appearing in the progeny of pure strains of plants which differed from the parental forms by appreciable qualities, obtained by de Vries in *Oenothera lamarckiana*, have been tested and in main confirmations of his results secured. The mutants did not in any case occur in a proportion greater than 5 per cent of the entire progeny and were identical with the forms secured in Amsterdam, with perhaps one exception. Seeds obtained from various parts of the world, from some localities in which the plant has been noted since 1854, were found to produce a low percentage of mutants.

AREA DENUDED FOR THE PURPOSE OF MAKING EXACT OBSERVATIONS ON THE MOVEMENTS OF DESERT PLANTS IN ITS REOCCUPATION.

ANCIENT BEACH LINE OF SALTON SEA ON THE RIGHT (22 FEET ABOVE SEA-LEVEL). MARGIN OF SEA ON MAY 22, 1906. MINOR BEACH LINES DENOTED BY PLANT FORMATIONS BETWEEN.

MARGIN OF SALTON SEA NEAR TRAVERTINE POINT, MAY 22, 1906.

The saline soil supports salt grass, creosote bush, and salt bush. The salt absorbed from the soil by the fresh water made a 1 per cent solution on May 22, 1906.

No real actuating cause for discontinuous variation in a hereditary strain having been found, attention was directed to the possibility of inducing changes in the hereditary elements in such a manner that the qualities transmitted would be altered or destroyed. A theoretical consideration of the subject seemed to indicate that the changes constituting the essential operation of mutation ensued in a stage previous to the reduction divisions in the embryo-sac, or the pollen mother cells. It was planned therefore to subject these structures to the action of chemical agents, not ordinarily encountered by the elements in question, at a time before fertilization occurred. The tests were planned to include the use of a solution of high osmotic value and mineral compounds, some of which are toxic in concentrated solutions and stimulating in the proportions used. The probability of success would be heightened with the number of ovules contained in any ovary operated upon, and therefore the common evening primrose, *Oenothera biennis, Raimannia odorata,* a relative of it and a member of the same family, *Begonia, Cleome, Abutilon, Sphæralcea, Mentzelia,* and others were experimented upon. Without recourse to the detail of the work, it may be stated that the use of sugar solutions (10 per cent) and solutions of calcium nitrate, one part in one to two thousand of distilled water with capsules of *Raimannia odorata,* and zinc sulphate in a stronger solution used with *Oenothera biennis* was followed by very striking results. In the first-named plant, there appeared in the progeny obtained from a few capsules of one individual, several individuals which were seen to differ notably from the type with the appearance of the cotyledons, and as development proceeded, it was evident that a mutant had appeared following the injections and nowhere else and thus to have some direct relation to the operation. The characters of the newly arisen form were so strikingly aberrant as to need no skill in their detection. The parent was villous-hairy; the mutant entirely and absolutely glabrous; the leaves of the parent have an excessive linear growth of the marginal portions of the leaf-blades and hence become fluted; the excess of growth in the mutant lies along the midrib and the margins become revolute. The leaves are widely different in width, those of the mutant being much narrower. The parental type is of a marked biennial habit, and near the close of the season the internodes formed are extremely short, which has the result of forming a dense rosette; the mutant forms no rosette by reason of the fact that the stem does not cease or diminish its rate of elongation and hence presents an elongated leafy stem, which continues to enlarge as if perennial. The first generation of the derivative came to bloom at the beginning of the present year, and bare mention of the existence of the derivative was given in a lecture before the Barnard Botanical Club at that time. The real value of the changes induced, however, lay in the transmissibility of the newly exhibited qualities. The flowers of the mutant were closely guarded and as

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soon as seeds were obtained these were planted to obtain a second generation. A few plants were obtained, which in every particular conformed to the new type and exhibited no return to the parental type.

Injections of the ovaries of *Oenothera biennis* were followed by the production of one individual, which was recognizably different from the parental type in many qualities, some of which were plainly apparent even in the earliest leaves of the seedlings.

Like the other derivative induced by the action of the chemical reagent, this form also transmits its qualities to the second generation. The parental form has been under observation for five years in cultures and in a wild condition. An aberrant form which appears to be ever-sporting has been previously figured, and while this form appeared in the injected or treated seeds in a normal proportion, yet the newest aberrant has not been seen elsewhere. The probability must be taken into account that it may be a mutant of rare occurrence, the cycle of which came within the experiments, but in either case it is plainly a mutant, and it only remains to be seen whether or not it was induced by the action of the zinc solution. The presumption seems to favor such a conclusion.

The atypic forms which have been tested to the second generation in both species are found to constitute mutants in the sense in which that term is used by de Vries, and are real and actual departures from the course of the hereditary strain. The capacity of the mutants induced in this manner for survival would depend entirely upon the environment into which they might be thrown.

The results of this experimentation have the additional interest that some simulation of their action may be reasonably predicated in nature. Thus the effect of radioactive substances such as spring and rain waters, the gaseous emanations in volcanic regions, the accidental and unusual formation of certain enzymes or substances in the vicinity of the egg-cells or pollen mother-cells, or the action of substances set free by foreign pollen which might penetrate to the region of the egg-cell in which pure fertilization ensued, or the stings of insects with the attendant liberation of inciting substances might well exert a similar action.

It is also to be noted that in these experiments the possibility is by no means eliminated that the reagents injected into the ovaries may not affect the egg-cell alone or at all, but may influence the elements carried by the pollen tube as it penetrates the placental tissues on its course to the egg-cells.

Two instances of sports or branches which bore characters not characteristic of the shoot of the species on which it was found were tested. In both cases the characters of the sport or variant were found to be fully inheritable without any admixture of the qualities of the main shoot of which the sport was a branch.

In a consideration of the subject of origin of new species many forms are encountered in nature which exemplify qualities of two other species either in a mosaic or an apparent intermediate grade in the ordinary taxonomic sense. Such forms are usually taken to be hybrids, although nothing but the actual resynthesis of the form by crossing the supposed parent or its culture to show resolutions in successive generation may yield any actual evidence upon the subject.

An oak tree of this character growing on the farm of Mr. John Bartram on the banks of the Schuylkill, some time previous to 1750, attracted attention as being of this hybrid character, and was named "Bartram's oak." In recent years similar forms have been found in a wide range of localities, the northernmost being Staten Island. The extended consideration of the subject by systematists seemed to lend favor to the supposition that it was a hybrid between *Quercus rubra* (the red oak) and *Q. phellos* (the willow oak). A number of acorns were procured from one of the trees on Staten Island in October, 1905, and sprouted in the cultures in the New York Botanical Garden. The resulting progeny, embracing nearly a hundred plantlets, constituted the second generation of the hybrid and included a series of forms which comprised individuals, some of which in this young stage simulated the red oak, others the willow oak, while the remainder showed various combinations of the parental characters. The origin and nature of this form was thus definitely established, and it is without doubt a hybrid product of the two oaks named. In conjunction with this work a comprehensive description of methods of testing the constitution of supposed hybrids has been formulated, and a list of reported hybrids incorporated in a paper now in press.

Hybridizations between *Oenothera lamarckiana* and *O. rubrinervis*, one of its mutant derivatives, resulted in a progeny which in the first generation split into the two immediate parents with no intermediates.

Induction and Inheritance of Fasciations in Stems, by Miss A. A. Knox.—Miss Knox, while assisting in the care of the cultures for the study of heredity carried on by Dr. D. T. MacDougal in 1905 and 1906 at the New York Botanical Garden, made an independent investigation of the causes, and transmissibility from generation to generation of the banding or fasciation of stems in evening-primroses. It was found in this work that the malformations in question were due to injury in all cases examined. The injuries are caused by larvæ which hatch and feed on the growing tips, attacking the cells while still in a meristematic condition. In most plants which are attacked the growing region is destroyed or its vitality impaired, or the surrounding leaves alone are consumed, the cells of the apex not reached, when no fasciations result. Certain swarms of larvæ by boring into the heart of the tip, inflict delicate wounds which may induce fasciation. The occurrence of the phenomena is dependent on three factors—the individual manipulation of

the insect, the extent and nature of the wound, and the innate character of the plant. Slow-growing species are more apt to fasciate than those of rapid development.

In the case of the fasciation from the rosette stage the injuries may be made by small larvæ in the soil, and usually date from the first stages of germination. The development is slow, and the causes must be traced far below any sign of their effect. The fasciations are ordinarily flat, but often ring-shaped, and intermediate stages between the two are common. The appearance of secondary meristems which later differentiate and which may eventually become incorporated with the bundle ring in conjunction with the alteration of the stem's shape is a frequent occurrence.

The section of a fasciated tip shows no deviation from the normal structure other than that of shape. Below the fasciated region inequalities in the amount of wood formed are indicative of the early injury.

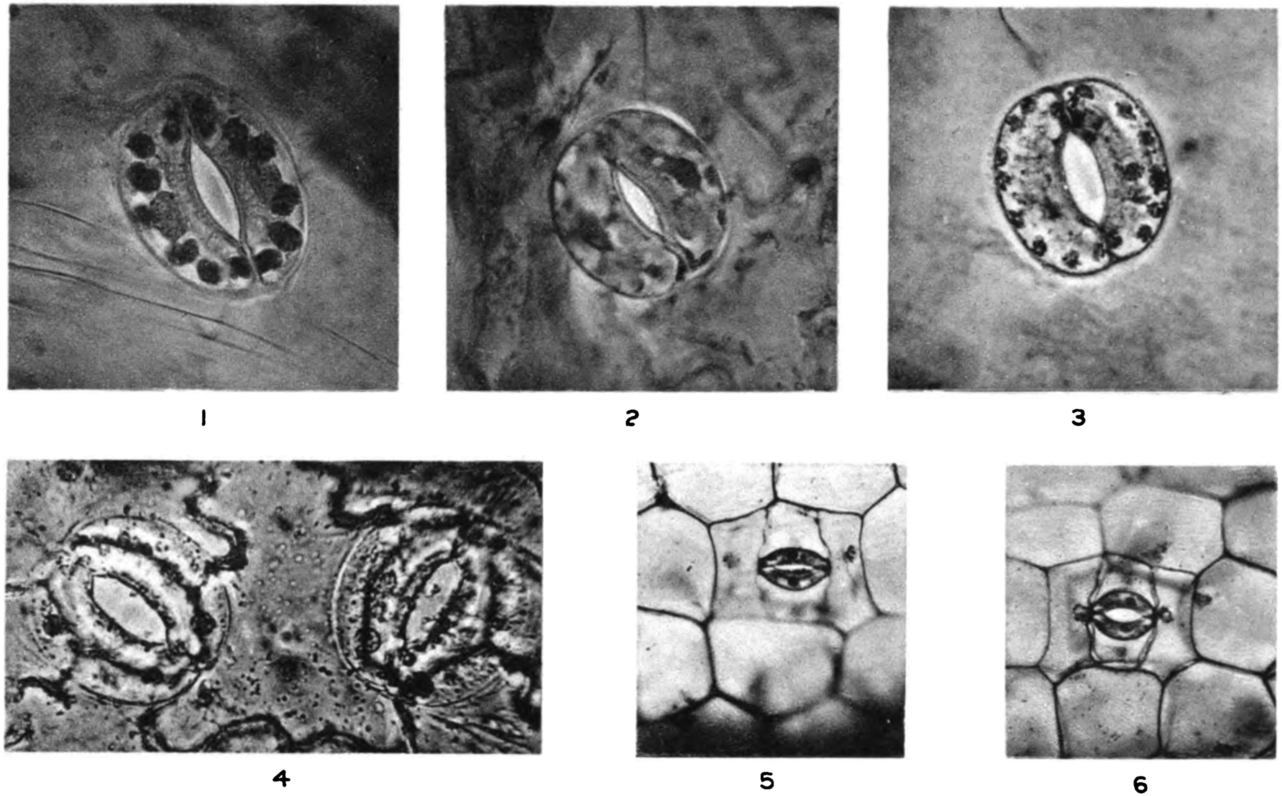
The progeny of fasciated plants shows no more tendency to fasciation than that of normal stock. Both may give an equally large percentage of fasciated stems.

An Automatic Rain-meter, by Mr. H. de Raasloff, C. E.—In the establishment of the various acclimatization cultures and of experimental tests in various arid localities it becomes highly desirable to obtain some data as to the precipitation, as well as of the soil-moisture. The latter may be determined by occasional tests, but some automatic apparatus for obtaining the total precipitation and registering it without the use of clockwork, which could be left alone for extended intervals, is found necessary. Mr. de Raasloff has kindly volunteered to design an apparatus, which uses the weight of the water secured to actuate the mechanism of measurement. A working model has been constructed which is now in operation in New York, and by observation of the workings of this instrument an improved form is being designed which promises to meet the needs described above.

Cooperative Work, Gifts, and Donations.—In a plan for a study of the horticultural results of Mr. Luther Burbank, Dr. D. T. MacDougal visited Mr. Burbank's plantations at Santa Rosa and Sebastopol late in May in company with President Woodward and Dr. C. B. Davenport and Dr. G. H. Shull, of the Department of Experimental Evolution.

Mr. Godfrey Sykes, of this Department, was detailed to the Solar Observatory on Mount Wilson, California, beginning July 1, 1906, to lay out and construct a roadway from near Pasadena to the summit of the mountain, an elevation of nearly 5,000 feet, and the duties in connection with this engineering problem detained him during the remainder of the year.

A number of naturalists have visited the Laboratory for the purpose of making observations upon organisms peculiar to the locality and to obtain material for extended researches. In addition numerous calls for material and assistance in collecting data have been met as fully as possible.



STAGES IN STOMATAL ACTION.

Fig. 1. The stoma or so-called breathing pore of a desert species of verbena (Verbena ciliata) prepared and photographed so as to demonstrate the large amount of starch, seen as dark bodies, occurring during the night.

Fig. 2. The same, from a leaf taken at about 9 A. M., at which time the starch is absent. Warm summer day.

Fig. 3. The same, taken at 9 A. M. on a cool day in spring, showing a moderate amount of starch to be present.

Fig. 4. The same prepared in such a manner that the shape of the stoma and the size of its opening are preserved as in life. The circular bodies are minute globules of oil which occur only at about 9 A. M.

Fig. 5. Stoma of the wandering jew (Tradescantia zebrina) preserved in its closed condition.

Fig. 6. The same, preserved in its open conditions.

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Prof. J. J. Thornber has contributed a set of herbarium specimens from southern Arizona to the Desert Laboratory, and has aided the staff at all times in the systematic study of the local flora. He has accompanied several of the field expeditions to various localities and also cooperated in the organization of the alpine plantation.

Prof. W. P. Blake has contributed a set of the report of the tenth census of the United States to the library of the Desert Laboratory, which is also the recipient of numerous publications given by members of the staff.

The publications received by the Department, not needed in its work or development have been contributed to the botanical libraries of several institutions.

By the courtesy of Dr. N. L. Britton, director-in-chief, the facilities of the propagating houses and experimental grounds of the New York Botanical Gardens have been given for the completion of work on plant breeding by Dr. D. T. MacDougal. Space in the laboratories has also been at the disposal of the Department for work in connection with these investigations. As a partial return for these courtesies the members of the staff of the Desert Laboratory have used every effort to aid in the investigation of the Cactaceæ by Dr. N. L. Britton and Dr. J. N. Rose, of the United States National Museum. Several shipments of living material from Nevada, Arizona, California, and various places in Mexico have been sent to these investigators.

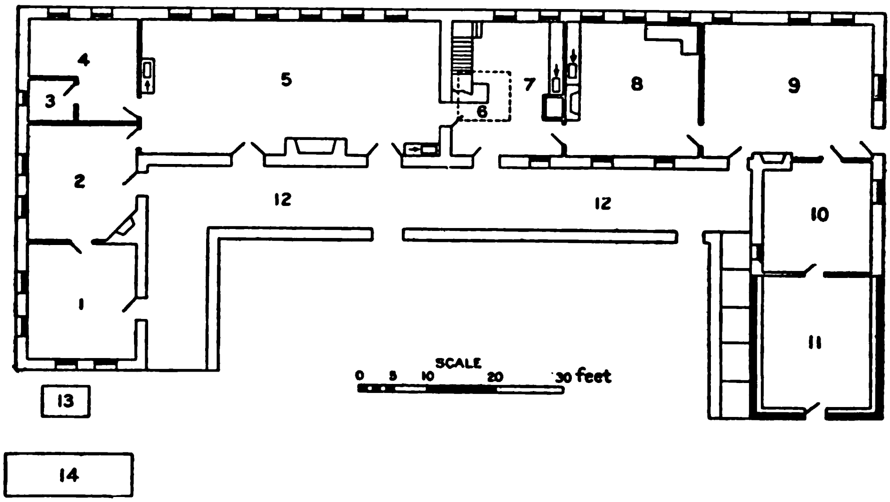
BUILDINGS AND EQUIPMENT.

Some of the facilities of the Desert Botanical Laboratory have been noted in previous reports, but it will be of interest to present here a complete summary of the equipment.

Reservation.—Beginning with the effort of the Chamber of Commerce of Tucson, in 1903, various additions have been made to the tract on which the Laboratory is located so that at the present time the grounds available for experimental work comprise 860 acres, immediately to the westward of the city of Tucson. Within this tract Tumamoc hill rises to a height of eight hundred feet above the lower mesas. These topographical features present a wide diversity of conditions for vegetation, and offer ideal conditions for many classes of experimental work. The Laboratory building is placed on a shoulder of the hill about midway to the top, and is reached by a mountain road of uneven grade which will shortly be replaced by one of better plan. During the present year the grounds were enclosed by a wire fence of three strands on cedar posts set a rod apart; it will be necessary, however, to reinforce this fence with a basal section of wire netting of close mesh to exclude domestic animals and to control jack-rabbits and other animals which would injure the increasing vegetation. Within a few months after the completion of this fence the difference between the vegetation and that of the surrounding areas was noticeable, and also an increased abundance in the number of

the wild animals. The proper inclosure of the tract places at the disposal of the investigator, hill-slopes, mesa, and wash, freed from the disturbances attendant upon free access of grazing animals and upon ranching operations.

Buildings.—Early in January plans were drawn and contracts let for the construction of additions to the Laboratory by which its capacity was more than doubled. With the completion of this construction work the Laboratory now extends around three sides of a quadrangle 126 feet in length with a short axis of 85 feet. Attached to the new arm of the building is a small glass house for experimental purposes, the adjacent room of the building being used as a work-room. The Laboratory now comprises a small work-room



KEY TO GROUND-PLAN OF DESERT LABORATORY.

1. Morphological laboratory.
2. Library.
3. Photographic dark-room.
4. Store-room and drawing-room.
5. Main laboratory.
6. Underground constant-temperature dark-room.
7. Chemical laboratory.
8. Physical laboratory.
9. Physiological laboratory and office.
10. Work-room for greenhouse.
11. Greenhouse.
12. Covered porch with parapet wall.
13. Soil thermographs.
14. Cold frames for plants.

for morphological work, a library and reading-room, a store-room and drafting-room, a photographic dark-room, a large laboratory for geographic and general work; a chemical and preparation-room with hoods and fume drafts; a laboratory for physical experimentation with independent piers for delicate instruments, a subterranean constant-temperature chamber, a large physiological laboratory and office; a small work-room and bath-room, and an experimental greenhouse. In addition one of the stone cross-walls has been continued through the roof by a brick pier, capped with soapstone, furnishing an elevated base for meteorological instruments, which is surrounded by a platform reached by a stairway from the physical laboratory. Here is installed the new type of evaporimeter designed by Dr. Livingston.

The constant temperature chamber was made by digging an excavation 6 by 6 feet, to a depth of 9 feet, in the rock in the center of the physical laboratory. This was walled with an air-space all around with brick and arranged with a heading so that the chamber can be entered without creating disturbing air-currents. The top of this chamber is insulated by planking and tarred paper. The bulb of a Hallock thermograph is suspended in the chamber, the recorder of which stands in the Laboratory above, so that a continuous record is obtained. In addition to the constant temperatures a perfect dark-room is also formed, which will be of the greatest usefulness in several investigations. Similar thermographs are employed in keeping a continuous record of the soil.

A small instrument shelter is in position a few feet to the westward of the Laboratory in which is placed a set of thermometers, thermographs, hygroscopes, etc., the data obtained from such sources being referred to in many of the researches carried on at the Laboratory.

Rainwater Reservoir.—For the ordinary operations of the Laboratory and for cultures of plants rainwater is necessary. To meet this need the entire laboratory was properly guttered and leaders were joined in a system which led to a small stone reservoir which was built in the line of the southern side of the quadrangle. Supply pipes from this reservoir were run to the physical and chemical Laboratories and to the small greenhouse.

Water System.—It was found necessary to reorganize the entire water supply of the Laboratory, as the old service was inadequate and the machinery faulty. To meet these conditions a lot was purchased in McKee's addition in the valley of the Santa Cruz and a well driven in it by contract. A pump was installed and a new line of 1½-inch dipped pipe was laid to the laboratory site, 7,000 feet distant and 400 feet above the well. Here a new stone reservoir, lined with brick, has been constructed with a capacity of 6,000 gallons. The lowest point in this reservoir has a head of 35 feet above the roof of the Laboratory, and it is believed provides an adequate supply for use, as well as for fire protection.

Miscellaneous.—A small building near the Laboratory furnishes quarters for an attendant, but should be replaced by one of fireproof construction. A public-comfort station was also built of stone near the main laboratory.

The equipment embraces two series of cold frames for cultural work, one of which has been put in place in the quadrangle, while the other is kept in a knock-down condition in order that it may be readily moved to any part of the reservation as occasion arises in the experimental work.

The alpine and austral plantations may be reached only by trails, and all material must be carried by pack animals. To meet this need a complete pack equipment has been organized, which comprises two pairs of heavy rawhide kyacks suitable for the transportation of instruments without damage. In addition, a fairly adequate camping outfit for mountain work has been provided.

BOTANY.

Burbank, Luther, Santa Rosa, California. Grant No. 310. *Experiments in plant development.* (For previous report see Year Book No. 4, p. 125.) $10,000.

Most strangely and most fortunately the great earthquake of April 18, 1906, which leveled the whole business section of this city in a few seconds, did no damage whatever to the greenhouse or to any of the plants.

Though in the very heart of destruction, not a pane of glass was cracked, not a leaf was broken, not a plant injured; even the rows of trees and plants at the Sebastopol farm, though in some places moved 4 feet out of line, were in no case injured in the least.

The work of crossing and the continual selection of promising variations continues as before, and an unusual number of new species and varieties of wild and locally known plants have been received and are being carefully inspected for characters of value either for economic or scientific purposes. Five hundred and twenty-two native species and varieties were received from native collectors in South America, 241 from Australia and New Zealand, and nearly 200 from various other parts of the world, among them many promising new types of Solanums, Opuntias, native wild fruits and vegetables, locally known and medicinal plants, trees, shrubs, and flowers, nearly all from seeds, thus obviating danger of insect pests and greatly lessening the expense and giving a better opportunity for selection by having greater numbers.

Some necessary draining has been done at the farm in spots too wet for cultivation, and the Home grounds have been made level and formed into raised beds to prevent the destruction of valuable plants by winter rains as formerly and to economize water used in summer irrigation.

Help to carry on the work is as usual the principal expense, but I now have loyal, intelligent helpers, so that nothing is wasted or lost by carelessness and inefficiency. The work is gradually being systematized and adapted to the new plans. It is perhaps not necessary to go into particulars here, but specially great progress is being made with the Opuntias, plums, nuts, and berries, among all of which unequaled opportunities for the study of scientific laws and principles have developed.

Blakeslee, Albert F., Harvard University, Cambridge, Massachusetts. Grant No. 340. *Investigation of sexuality in lower fungi.* (For previous report see Year Book No. 4, p. 275.) $1,000.

Abstract of Report.—Investigations on the germination of zygospores begun the year previous have given certain definite results, which may be summarized as follows:

(1) The zygospores of the Mucorineæ require a longer or shorter period of rest before they become capable of germination.

(2) The germination of the zygospores of the homothallic species Sporodinia is pure homothallic.

(3) In the germination of the zygospores of the heterothallic species *Mucor mucedo* the segregation of sex is completed at some time before the formation of sporangial spores, and all the spores in a given germ sporangium are of the same strain, either (+) or (—).

(4) In the germination of the heterothallic species *Phycomyces nitens* a segregation of sex may take place at the formation of spores in the germ sporangia, but is only partial.

(5) In addition to (+) and (—) heterothallic spores, spores are formed which give rise to homothallic mycelia characterized by a production of spirally coiled aerial outgrowths termed pseudophores and the occasional formation of homothallic zygospores.

(6) The sexual character in these homothallic mycelia is unstable, and in their sporangia a segregation again takes place and (+), (—), and homothallic spores are produced. (Annales Mycologici, IV, pp. 1–28, pl. 1, 2 text figs., 1906.)

The investigation of the distribution in nature of the sexual strains of the common bread mold (*Rhizopus nigricans*) has been extended. (Science, n. s., XXIV, pp. 118–122, July 27, 1906.)

The results obtained from a study of zygospore germinations in the Mucorineæ have led to an investigation of the sexual condition in the sporophyte of Bryophytes. (Botanical Gazette, XLII, pp. 161–178, fol. VI, 3 text figs., September, 1906.) For one form (*Marchantia polymorpha*) it has been definitely determined that a single capsule contains both male and female spores. The exact point in the development of the capsule at which the segregation of sex takes place has not as yet been determined.

A study of the influence of the composition of the substratum upon the sexual reproduction has been begun and is still in progress. The forms under investigation are included in the following list of species, arranged according to the type of their sexual reproduction:

HOMOTHALLIC.

1. Sporodinia grandis.
2. Spinellus fusiger.

3, 4. Mucors I and II.

Heterogamic.

5. Zygorhynchus Moelleri.
6. Zygorhynchus heterogamus.
7. Dicranophora.

HETEROTHALLIC.

1. Mucor Mucedo.

2–7. Mucors III to VIII.

8. Rhizopus nigricans.
9. Phycomyces nitens.
10. Circinella umbellata.
11. Cunninghamella echinulata.
12. Absidia caerulea.
13. Absidia repens.
14. Absidia sp.
15. Helicostylum.
16. Syncephalastrum.
17. Mucor N, n. gen.

Olive, Edgar W., University of Wisconsin, Madison, Wisconsin. Grant No. 271. *Researches on the life histories and cytology of certain lower plants.* (For previous reports see Year Book No. 2, p. xxvii; Year Book No. 3, p. 131, and Year Book No. 4, pp. 130–131.) $1,000.

Abstract of Report.—Three papers, representing part of the writer's earlier work as research assistant of the Carnegie Institution of Washington, have been published, one on Oscillatoria and two on the structure and development of Empusa.

Several other papers have been partially completed, two on Diplophrys and other colonial organisms, one on *Empusa muscæ*, one on Ceratiomyxa, and one on Basidiobolus. Some preliminary work on the rusts has shown that the results of certain recent writers on the group are, at least in the essentials, not contradictory, as has been supposed.

Swingle, Walter T., U. S. Department of Agriculture, Washington, D. C. Grant No. 235. *Investigation of the lines of force in living cells and the effects of electromagnetic and electrostatic fields on such lines of force.* (For previous report see Year Book No. 4, pp. 131–132.) $1,500.

Abstract of Report.—The most important progress in connection with this work during the past year has been the bringing up to date of the bibliography of the literature of the cell. This index now comprises 6,774 cards, being duplicate entries of 3,387 titles. These titles were copied photographically from the bibliographies of cytology and histology, published in the Anatomischer Anzeiger from January 1, 1900, up to date. Photographs were also made of the bibliography in the second edition of Prof. E. B. Wilson's work on the cell, which includes titles up to 1900. By means of this new card index it is possible to find arranged under any author's name practically all of the titles of his published work relative to cytology. This is a matter of very great importance in a science which is progressing so rapidly and which has such a scattered literature. Heretofore it has been almost impossible to avoid overlooking some of the most recent and important contributions on the subject owing to the difficulty of keeping track of the literature relating to it.

The importance of such a bibliography in the study of lines of force in the living cell is very great, since it is a new point of view involving explanations in very different terms from those given by most of the investigators themselves—that is, a description or drawing considered of minor importance by the author for the problems he had in view may prove to be of very great import for demonstrating the existence of lines of force in the cell.

Arrangements have been made to utilize new forms of the microscope for the study of the minute details of cell structure. In this work the naphthobrom immersion lens, having a numerical aperture of 1.63, will be used for visual examination of fixed material and the monochromatic lens for ultra-

violet light will be used for making photographs of living cells and also of preparations made from fixed material. The latter lens has a resolving power of 2.5. It is believed that the utilization of these microscopic objectives having a far greater resolving power than any which have been used up to now will permit the investigations to be carried on to much better advantage than has been possible heretofore.

During the past year several articles have been published by writers who accept the doctrine that there are lines of force in the living cell. At least one of these, by Dr. Marcus Hartog, in the Proceedings of the Royal Society of London, December 1, 1905, gives some new evidence demonstrating the existence of what he calls "chains of force," which may prove very helpful in explaining the appearances seen in living cells. These "chains of force" can be formed artificially if fine iron filings are placed in a viscid medium between the poles of a powerful magnet. These chains have a remarkable tensile strength. They resist the influence of gravity and can be pushed aside with a glass rod, or swayed by currents without breaking. They are more permeable to the magnetic lines of force than is the surrounding medium, and consequently the medium adjoining one of these "chains of force" is almost free from lines of force.

It is confidently believed that it will shortly be established to the satisfaction of cytologists that the cell is the seat of a hitherto unknown system of forces and that these forces are one of the most important agencies at the disposal of the cell in carrying on its structural work. These kinoplasmic forces are as important in connection with cell division, the formation of the organs of the cell, and the building up of tissues as enzymes have proven to be in carrying out the physiological activities of the cell.

CHEMISTRY.

Acree, Solomon F., Johns Hopkins University, Baltimore, Maryland. Grants Nos. 204 and 372. *Study of pinacone-pinacolin rearrangement and of urazoles.* (For previous report see Year Book No. 4, pp. 134–135.)

$1,300.

Report.—Dr. Acree has continued the investigations on the pinacone rearrangement and the urazoles. The work on the urazoles will be reported on later. In the study of the pinacone rearrangement, a phase of this subject, of biological importance, was taken up in conjunction with Dr. J. E. Hinkins in the investigation of some cases of abnormally acid saliva. It was thought possible that carbohydrates in the saliva undergo a rearrangement into the acids found to be present.

A number of individuals suffering from erosion of the teeth, attended with abnormally acid saliva, presented themselves to aid in the work. The saliva was titrated with N / 10 potassium hydroxide solution and phenol phthalein and found to vary with the different individuals from N / 300 to N / 50. An increase in the acidity of the saliva was attended by an increase in the severity of the erosion of the teeth. Investigations were made to throw light upon the following questions: (1) Is the acid generated wholly or partially in the saliva by aerobic or anaerobic bacteria present in the mouth? (2) Is the acid generated appreciably by enzymes present in the saliva? (3) Is the acid generated entirely or in part in the mouth or does the saliva issue acid from the ducts?

(1) A study of the rate of formation of acids by various mouth-bacteria, such as *B. coli communis*, *Staphylococcus pyogenes aureus*, etc., in different culture media led to the conclusion that bacteria are hardly at all concerned in the formation of the acid in the saliva.

(2) Similarly, a study of the rate of hydrolysis of triacetylglucose by various enzymes led to the belief that enzymes play only a very small rôle in the generation of acid in the saliva after it enters the mouth.

(3) A study of samples of saliva obtained from different individuals by catheterizing the left Steno's duct showed this saliva to be as acid as the total saliva obtained from the mouth. A bacteriological examination of the saliva issuing from the ducts of the different individuals showed these salivas to be free from bacteria. The conclusion, then, is that the saliva is secreted acid in the glands.

In the further study of erosion of tooth structure some new analyses of teeth were made, and a new color test for proteids was investigated. The results of these researches are embodied in three articles, now ready for publication, which will appear with the titles "On Abnormally Acid Saliva," "On the Composition of the Dentine and Enamel of Human Teeth," and "A Formaldehyde Color Test for Proteids (I)." The investigations will be continued.

Bancroft, Wilder D., Cornell University, Ithaca, New York. Grant No. 323. *Systematic study of alloys.* (For previous reports see Year Book No. 2, p. xxix, and Year Book No. 3, p. 104, and Year Book No. 4, pp. 133–134.) $1,000.

The following papers have been published during the year:

The alloys of antimony and tin. F. E. Gallagher. Jour. Phys. Chem., v. 10, p. 93 (1906).
Electrolytic corrosion of the bronzes. B. E. Curry. Ibid., v. 10, p. 474 (1906).
Electrolytic precipitation of the bronzes. B. E. Curry. Ibid., v. 10, p. 515 (1906).

The paper on the constitution of the bronzes is in the press and will appear in November. In the work on the electrolytic corrosion of the bronzes Mr. Curry has shown that there is a definite relation between the anode efficiencies and the constitution of the bronzes. Sudden changes in current efficiency take place only at points where the crystalline structure changes, though not necessarily at every point at which such a change takes place. The "breaks" occur at different places in different solutions, but we are not able to predict the position of the "breaks." In all solutions except chlorides the bronzes become passive over a greater or lesser range of concentrations. It has been shown that this is due to the formation of a surface film of stannic oxide. There is no relation between the corrodibility and the electromotive force of the alloys, but the electrolytic and the chemical corrosions have been shown to run parallel.

In the electrolytic precipitation of the bronzes satisfactory deposits were obtained from acid oxalate solutions, and data are given for the relation between composition of solution and composition of cathode deposit. Under the conditions of the experiments the electrolytically precipitated bronzes are the equilibrium forms.

Some work has been done during the year on the constitution, corrosion, and tensile strength of aluminum bronze, but a report on this will have to be deferred till next year. A tentative diagram for the carbon steels has also been worked out, but the confirmatory data are still incomplete.

Baskerville, Charles, College of the City of New York, New York, N. Y. Grant No. 237. *Continuation of investigation of the rare earths.* (For previous reports see Year Book No. 3, p. 105, and Year Book No. 4, pp. 136–148.) $2,000.

Professor Baskerville submits the following abstracts of several investigations carried out by himself and Dr. Fritz Zerban with the aid of grants from the Carnegie Institution of Washington.

PREPARATION OF METALLIC THORIUM.

It was shown by previous experiments (Fourth Year Book of the Carnegie Institution of Washington, pp. 139–142) that metallic thorium of a high degree of purity may be obtained by the reduction of thorium potassium

fluoride with aluminum under suitable conditions, and subsequent treatment of the regulus obtained with caustic alkali to remove the excess of aluminum. The metal prepared in this way, however, was a crystalline powder which still contained some impurities. The removal of these impurities was absolutely essential for the subsequent determinations of the physical and chemical properties of the metal. The only effective way for accomplishing this is remelting it repeatedly. But this method can not be applied to thorium under ordinary conditions, because the melting point of this metal is extremely high and because it is attacked by all inert gases, forming hydride, nitride, or carbide. It can not be fused under a cover of an alkaline chloride, because the metal oxidizes at a temperature much lower than the melting points of the chlorides. It is necessary, therefore, to fuse it in an absolute vacuum. We hope to carry out these experiments in a vacuum resistance furnace of the Arsem type.

In the meantime some other methods were tried with the view of obtaining the fused metal directly. Muthmann and his pupils showed that the metals of the cerite group may be obtained by electrolysis of the fused anhydrous chlorides in a water-jacketed copper crucible, using a very thin carbon rod as cathode and a thick carbon anode. In order to find out the most favorable conditions, samples of metallic cerium, lanthanum, and neodymium were prepared with satisfactory results. It was further tried to obtain these metals from their respective double fluorides with potassium by electrolysis. The double fluorides were prepared in the following way: Concentrated solutions of the chlorides or nitrates were heated on the water-bath and pure hydrofluoric acid added. The gelatinous precipitate obtained at first soon changed into a fine, heavy, sandy powder which could be easily filtered by means of a hard rubber funnel and washed with water. It was then dried at 120° C. and finally fused with 3 molecules of potassium fluoride. When working under the same conditions as Muthmann, these double fluorides were readily fused by the current used, but in no case was metal formed, as Muthmann had also observed in the case of didymium. By changing the proportions of rare-earth fluoride to potassium fluoride the melting point and the resistance of the substances was also altered. By electrolysis of these bodies metal could not be prepared.

After these preliminary experiments the preparation of metallic thorium was attempted. As the fluoride of this element is prepared much more readily than the anhydrous chloride, the investigation was begun with the double fluoride of thorium and potassium made in exactly the same way as those of the cerite metals, mixing two molecules of potassium fluoride with one of thorium fluoride. The material fused very readily in the electrolytic cell; however, no metal was obtained. Next to this experiment the electrolysis of double chlorides of thorium was attempted. Anhydrous thorium chloride was prepared in a porcelain tube by Matignon's method, *i. e.*, by

heating oxide in a current of chlorine mixed with vapors of sulphur chloride. The chloride obtained in this way was mixed with one-third of its weight of barium chloride and with sufficient sodium chloride to make up for two molecules of sodium chloride altogether. The barium chloride was added to increase the temperature of the electrolyte; this peculiar property of barium chloride was discovered by Muthmann. Experiments with the view of electrolizing the double chlorides are in progress.

A third method which presented itself was the use of metallic calcium as a reducing agent acting in a similar way as aluminum, since calcium is now one of the cheaper metals and can be had in large quantities. A great number of experiments was undertaken, using oxide, anhydrous chloride, double chlorides or fluorides, changing the proportions of the thorium compound to the reducing agent, and using outside heat or Goldschmidt's ignition method. In most cases metallic thorium was obtained in the form of a gray powder, but never as a regulus. Although calcium has a higher reducing power than aluminum, the heat of combustion is not sufficient to melt the metal as well as the calcium oxide produced.

INVESTIGATIONS ON METALLIC YTTRIUM, GLUCINUM, CERIUM, AND ZIRCONIUM.

In connection with the experiments on metallic thorium an investigation on some other rare-earth metals was begun. For the material, which consisted of pure rare-earth preparations and of 5 pounds of Norwegian gadolinite, we are indebted to the Welsbach Light Company, at Gloucester, New Jersey, and especially to their chemist, Dr. H. S. Miner.

The gadolinite was treated in the following way: It was ground to a fine powder and decomposed by heating with crude hydrochloric acid. The silica was then filtered off and the solution evaporated to dryness in order to render insoluble that part of the silica which remained dissolved after the first treatment. The residue was dissolved in very dilute hydrochloric acid, the solution filtered again, diluted to about 10 liters, and slowly poured into a solution of 3 pounds oxalic acid in 15 liters of water, and the whole allowed to stand for two days. It was then filtered and washed. The yttria was extracted from these oxalates by Drossbach's method, which consists in dissolving the moist oxalates in a strong solution of potassium carbonate and pouring this solution into a large quantity of hot water, whereby the cerite-earths are precipitated. The filtrate was acidified with hydrochloric acid, which precipitated the oxalates again. These were filtered off, washed, dried, and ignited. In this way a first portion of yttrite earths was obtained, which was further purified by precipitation with ammonia. The hydroxides, after thorough washing, were dissolved in hydrochloric acid.

The other portion of the double carbonates which was insoluble in water still contained a large quantity of yttrite earths. The precipitate was, there-

fore, dissolved in hydrochloric acid and reprecipitated with oxalic acid. After converting into oxide this portion amounted to 290 grams. It was dissolved in hydrochloric acid, the solution evaporated to dryness, the residue taken up with water, poured into a mixture of 2.3 kg. of potassium sulphate and 15 liters of water and stirred for four days. The solution obtained by this process was filtered, precipitated with ammonium hydroxide, the precipitate thoroughly washed and redissolved in hydrochloric acid. This solution of yttrite chlorides was then combined with the one obtained by the carbonate process.

In order to find out the approximate composition of the material prepared in this way, an atomic weight determination was carried out by the well-known method of Krüss, as described by C. R. Böhm. 0.5126 gram oxide gave 0.9852 gram sulphate. The atomic weight calculated from these figures is *106.15* for a trivalent element, a perfectly satisfactory number for crude yttria.

It seemed desirable, on account of the small quantity of material and its high value, to undertake the first experiments with this crude yttria instead of first extracting the single constituents from it. Thus far four electrolyses have been run with the anhydrous chloride mixed with barium chloride, but in these only pulverulent metal was obtained. The double fluorides, which were also tried, did not give satisfactory results. The experiments will be continued.

The glucinum contained in the first filtrate from the rare-earth oxalates and contaminated mainly with iron was purified by the usual methods with ammonium carbonate and ammonium sulphide, and will be used for an investigation of metallic glucinum.

In connection with the experiments in which it was tried to reduce thorium by means of metallic calcium, the behavior of this latter metal towards ceria, zirconia, and their respective haloid salts was studied. Only in one instance, by using anhydrous cerium chloride, mixing it with the calculated amount of calcium filings and igniting with Goldschmidt's ignition mixture, small globules of metallic cerium were obtained, but the heat produced was not sufficient to melt both of the products of the reaction. In all other cases only pulverulent metal was obtained.

ON THE ATOMIC WEIGHT OF CAROLINIUM.

The investigation on the elementary nature of thorium, published in previous Year Books, was criticized by Meyer and Gumperz. These authors used, for the preparation of the anhydrous chloride, a method similar to that described by Charles Baskerville, but which differs from it in certain important details. Whereas the latter author found different values for the atomic weights of the three fractions, Meyer and Gumperz claim that there

is no such difference, and that all of the fractions have the atomic weight of old thorium. Charles Baskerville, in a note discussing Meyer and Gumperz's paper, called attention to the necessity of exactly following the procedure described by him for the preparation of the anhydrous chloride.

This criticism necessitated a redetermination of the atomic weights of the fractions prepared by the original process, combined with a comparative study of the methods which have been suggested for the determination of the atomic weight of thorium, and are based upon the relation of oxide to adhydrous or hydrated sulphate.

In the determinations reported on below, the purely physical manipulations, as heating and weighing, were carried out with the same precautions as have been described in the previous work. For heating the sulphate and oxide to a certain fixed temperature, our electric resistance furnace, with heating space for two crucibles, was used. We had found in the earlier work that the two counterpoised platinum crucibles when heated to 1,200° C. lost in weight at a different rate. This difficulty was easily avoided by heating to only 1,050° C., at which temperature the difference in the loss is immeasurable. It was ascertained by experiment that at this temperature thorium sulphate is quantitatively converted into oxide.

In one experiment the use of counterpoised quartz crucibles was tried. They could easily be brought to constant weight at 1,200° C., but it was found that at this high temperatnre the thorium-oxide reacted with the silica, apparently forming a silicate. This silicate having a different coefficient of expansion, the crucible cracked in one place. It is apparent from this observation that quartz crucibles can not be safely used for like experiments.

Before weighing, both crucibles were always inclosed in glass-stoppered weighing bottles of thin glass and of approximately the same weight. This precaution was taken in order to avoid errors resulting from the highly hygroscopic properties of both the sulphate and the oxide.

Leaving out the first possible method for the atomic weight determination, which consists in heating the weighed oxide with sulphuric acid repeatedly and drying at 400° C. to constant weight, there are two more processes available.

The first one is accomplished by dissolving pure hydroxide in hydrochloric acid in a weighed platinum crucible, adding a slight excess of sulphuric acid, evaporating on the water-bath, and then heating in an air-bath, at 400° C., to constant weight. The sulphate thus obtained is then converted into oxide by glowing.

Experiments carried out in this way before had given 241 for crude carolinium and 258 after several crystallizations of the chloride.

Two more determinations made in the same way with material prepared by Baskerville's method resulted in the following figures: 0.9706 gram

sulphate gave 0.6001 gram oxide, atomic weight 227.3; 0.9745 gram sulphate gave 0.5973 gram oxide, atomic weight 221.5. If the four results obtained by this method be compared, it is evident that it does not give satisfactory results and that it can not be used for atomic weight determinations.

The third possible method was used by Meyer and Gumperz. These authors expressly state that only a crystallized sulphate gives exact results, and that even among the various crystallized sulphates of thorium only those with 8 and with 9 molecules of water of crystallization are suitable for the determination, whereas the tetrahydrate yields unsatisfactory results. The octo- (or ennea-) hydrate must be dried at 400° C., whereby neutral anhydrous sulphate is obtained. This is then converted into oxide and the calculations are made from the relation $Th(SO_4)_2 : ThO_2$. The authors say: "Our experiences have shown us that the method described here is the only one which can be used for the preparation of a neutral anhydrous sulphate."

In order to control this statement also in a positive way, crystallized sulphate was prepared according to the directions given by Meyer and Gumperz. The evaporation of the sulphate solution was carried out at *ca.* 35° C. in a round flask, constantly drawing dry air through the liquid, in order to accelerate the evaporation. After about two-thirds of the liquid had evaporated, a mass of very small, fine crystals separated out, which were dried in the air without heating.

The determination made with this substance gave the following results:

1.4893 gram hydrate gave 1.2136 gram anhydride and 0.9326 gram oxide.

The small quantity of water, which corresponds to only 18.51 per cent, shows that the substance obtained could not be the one which should have been expected. The atomic weight of the element contained in it, assuming the formula $M(SO_4)_2$ for the anhydrous sulphate, would be as high as 499. Such a figure is altogether out of question. The compound must, therefore, have a different composition. Assuming 256 as atomic weight of the metal contained in it, a simple formula can not be constructed, but on the basis of 232 for that figure the formula $ThSO_4O ; 4.5H_2O$ is found.

The compound, according to the figures given above, contains 62.62 per cent ThO_2, 18.86 per cent SO_3, 18.51 per cent H_2O. By dividing these numbers by the molecular weights respectively, we obtain the relation 0.237 : 0.237 : 1.028, which is equivalent to 1.00 : 1.00 : 4.34. The quantity of water found by this analysis is, therefore, a little smaller than required by the formula given above.

The correctness of the formula was confirmed by a direct analysis, made in the following way: 0.5453 gram of the substance was dissolved in water, the thoria precipitated with ammonia and the sulphuric acid determined in the filtrate by means of barium chloride 0.3353 gram ThO_2 and 0.3015 gram $BaSO_4$ were thus obtained.

The results of the two analyses, using different methods, are as follows:

	Calculated for $ThOSO_4$; 4.5 H_2O.	Found.	
		I.	II.
	Per cent.	*Per cent.*	*Per cent.*
ThO_2	62.12	62.62	61.49
SO_3	18.82	18.86	18.98
H_2O	19.06	18.51	(19.53)
	100.00	99.99	100.00

If the anhydrous salt be taken as a basis for the calculation, we find the following figures, agreeing closely:

	Calculated for $ThOSO_4$.	Found.
	Per cent.	*Per cent.*
ThO_2	76.74	76.84
SO_3	(23.26)	(23.16)

Since, in this particular instance, we failed to obtain the octo- or ennea-hydrate, preparing instead a substance heretofore unknown, we have begun a series of determinations with a sample of octohydrate.

In conclusion it may be remarked that, whereas the equilibria of the various hydrates of thorium sulphate between 0° and 100° C. have been made the subject of an extensive study by Roozeboom, there are no data at hand concerning the decomposition curves of the tetrahydrate and of the anhydride at temperatures above 100° C. For an exact revision of the atomic weight of thorium these data will be now indispensable.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. Grant No. 293. *Researches upon atomic weights, particularly of manganese.* (For previous reports see Year Book No. 3, p. 105, and Year Book No. 4, pp. 149–150.) $1,000.

Five investigations have been carried on by Professor Baxter or under his direction.

(1) With Dr. Murray A. Hines the investigation upon the atomic weight of manganese, begun with Grant 154 (see Year Book No. 4, p. 149, 1905) by analysis of manganous bromide, was continued by the analysis of manganous chloride. This salt was prepared for analysis by fusion in a current of hydrochloric acid gas which had been dried with sulphuric acid. Then, after solution in water, the chloride was titrated against a weighed equivalent amount of the purest silver. Finally the precipitate of silver chloride was collected and weighed. The result for the atomic weight of manganese obtained from the analysis of manganous chloride is essentially identical with that previously found by analysis of manganous bromide, the final

average from both series being 54.96, referred to silver 107.930. The complete account of this investigation will soon be published in the Journal of the American Chemical Society for November, 1906, and also in the Zeitschrift für anorganische Chemie.

(2) An investigation upon the atomic weight of cadmium, begun some years ago by Dr. Hines by analysis of cadmium chloride (see Journal of the American Chemical Society, **27**, 222 (1905), and Zeitschrift für anorganische Chemie, **44**, 158 , was continued by Dr. Hines and Mr. Harry L. Frevert by the analysis of cadmium bromide. Here also weighed portions of the fused salt were first titrated against pure silver, and then the precipitated silver bromide was collected and weighed. Since in the investigation upon manganous chloride it was found that phosphorus pentoxide is slightly attacked by hydrochloric acid gas, new analyses of cadmium chloride were completed, in which the salt was fused in a current of hydrochloric acid which had been dried by concentrated sulphuric acid only. These analyses, however, agreed very closely with the analyses of cadmium bromide, and also with the previous analyses of cadmium chloride, although in the earlier work phosphorus pentoxide had been used as a drying agent for the hydrochloric acid gas. The atomic weight of cadmium, referred to silver 107.930, was found to be 112.47. The results of this research have already been published in the Journal of the American Chemical Society, **28**, 770 (1906), and in the Zeitschrift für anorganische Chemie, **49**, 415.

(3) The atomic weight of bromine was determined by Professor Baxter both by synthesis of silver bromide from weighed amounts of silver and by the conversion of silver bromide into silver chloride. If the atomic weight of silver is 107.930, the atomic weight of bromine is found to be 79.953. This investigation has already been described in full in the proceedings of the American Academy of Arts and Sciences, **42**, 201 (1906), the Journal of the American Chemical Society, **28**, 1322, and the Zeitschrift für anorganische Chemie, **50**, 389.

(4) Dr. Hines also commenced an investigation upon the atomic weight of chromium. Silver chromate was precipitated by addition of a dilute silver nitrate solution to a dilute solution of ammonium chromate. After being dried at 200° the salt was dissolved in nitric acid and the silver was precipitated by either hydrochloric or hydrobromic acid. Then the precipitated silver halide was collected and weighed. Difficulty was experienced in preparing silver chromate free from dichromate. Furthermore, it was found impossible to eliminate all moisture from the silver chromate; hence a correction for this moisture was determined. This research is not yet completed. The reduction of silver chromate in hydrogen is also under investigation.

(5) With Mr. George S. Tilley an attempt to refer the atomic weight of iodine directly to that of oxygen has been made through the analysis

of iodine pentoxide. Pure iodic acid was made by the action of fuming nitric acid upon iodine in quartz vessels. The iodic acid, after crystallization in quartz vessels, was dehydrated in a current of dry air and the resulting pentoxide was weighed. Then it was dissolved in water, reduced with sulphurous acid, and titrated against the purest silver. This investigation is still in progress.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 267. *Investigations on hydrates in concentrated aqueous solutions.* (For previous reports see Year Book No. 2, p. xxx; Year Book No. 3, p. 106, and Year Book No. 4, pp. 151–152.) $1,000.

During the past year a study has been made of the absorption spectra of such salts as cobalt chloride, copper chloride, and copper bromide, as affected by the presence of certain colorless salts with large dehydrating power, such as calcium chloride, calcium bromide, and aluminium bromide. The object of this part of the investigation, which has now been in progress several years, was to see what evidence could be obtained for or against the present hydrate theory proposed about six years ago, from a study of the absorption spectra of certain colored substances as affected by the presence of other substances which have even greater power to combine with water than the colored substance in question. By adding the colorless substance in different quantities we hoped to throw light on the relation between hydration and mass action.

A Hilger prism spectroscope was used for observational work, and a grating spectrograph for the photographic records. The solutions were placed in cells provided with quartz ends, so as to be able to obtain results also in the ultra-violet region.

The freezing-points and conductivities of many of the solutions were also measured.

Very satisfactory spectrograms were obtained, showing the change in the absorption spectra of cobalt chloride, cobalt bromide, and aluminium chloride; by the addition to solutions of each of varying amounts of calcium chloride, calcium bromide, and aluminium chloride.

The wave-lengths of the absorption bands in all of the 34 spectrograms were carefully measured. The results from aqueous solutions are entirely unambiguous as bearing upon the hydrate problem. The color changes in the solutions are not due to the presence of double salts, as Engle supposed. They are not to be accounted for on the basis of ionization, as Ostwald had thought. They are not due to the presence of complex ions, as Donnan supposed, but to a change in the hydration of the colored salt or the ions resulting from it.

The evidence furnished by the spectroscopic work for the general correctness of the present hydrate theory seems to be conclusive. Indeed, the interpretation of the spectrograms in terms of this theory is perfectly simple,

while it is impossible to interpret them in terms of any other conception thus far advanced.

Having obtained such satisfactory results in aqueous solutions, we turned our attention to solutions in non-aqueous solvents, working with methyl and ethyl alcohols and acetone. To work with these solvents a special form of cell was devised for holding the solutions, which could be assembled entirely without cement.

We worked with cobalt chloride in methyl alcohol, ethyl alcohol, and acetone, and photographed the change in the absorption spectra produced by the addition of varying amounts of water. In a similar manner work was done with copper chloride in methyl alcohol, ethyl alcohol, and acetone; and copper bromide was studied in methyl and ethyl alcohols.

The bearing of the results obtained with non-aqueous solvents on the present theory of hydrates is interesting. The fundamental interpretation given to the widening of the absorption bands is that the vibrations of the resonators were becoming less damped, which was due to the dehydration of the vibrating systems. We should then expect that the absorption bands, characteristic of a given colored salt, would be widest for the anhydrous solutions, and would become narrower and narrower on the addition of more and more water. The thirteen spectrograms obtained with non-aqueous solutions all confirm this conclusion. The work in non-aqueous solvents is then as confirmatory of the present hydrate conception as that in solutions in water itself.

The results of this investigation will soon be published in the form of a monograph by the Carnegie Institution of Washington.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 324. *On the measurement of osmotic pressure.* (For previous reports see Year Book No. 2, p. xxx; Year Book No. 3, p. 108, and Year Book No. 4, pp. 152–153.) $1,500.

The work of the past year has consisted in (1) the construction of somewhat elaborate automatic devices for the maintenance of constant temperatures; (2) the remeasurement of the osmotic pressure of cane-sugar; and (3) the measurement of the osmotic pressure of glucose.

During the first series of measurements of the osmotic pressure of cane-sugar great difficulty was experienced with certain "thermometer effects" in the cells—that is, "temporary fluctuations of pressure which follow changes of temperature, and are due to the expansion or contraction of the liquids in the cell, and not to actual variations in osmotic pressure." It was determined to eliminate these by constructing a bath in which very nearly constant temperatures could be maintained automatically for any desired length of time. The outcome of this part of the work was two large water-baths—each sufficient for the accommodation of six cells, in

which, by means of electrically driven pumps, the water (300 liters) is kept in constant and uniform circulation, and the air in the enclosed space above the water is made to pass continuously through pipes lying in the water. By surrounding these baths with a thick covering of hair very slow changes of temperature were secured despite considerable and rapid variations in external temperature conditions. Nevertheless, we proceeded to devise means for maintaining nearly constant temperatures in the space outside the baths. For this purpose both electric and gas stoves were employed, and for the latter there was devised a new form of gas regulator. Finally, to regulate both the electric and the gas stoves, a new form of electric mercury thermostat was constructed in which *sparking*—the usual difficulty with this class of instruments—is suppressed by spanning the spark gap with a resistance which bears a certain relation to the potential of the battery.

A full account of the measures taken to eliminate the "thermometer effects," which had given us so much trouble in the earlier work, has been published in the American Chemical Journal, volume XXXVI, and it is only necessary to state here that they were entirely adequate for the removal of the most serious obstacle to the accurate measurement of pressure which we have encountered.

With the improved facilities mentioned above, for the maintenance of constant temperatures, a careful redetermination of the osmotic pressure of cane-sugar solutions, ranging in concentration from 0.1 to 1.0 *weight-normal*, was undertaken. This part of the work has been completed, and the results have been published in the American Chemical Journal, volume XXXVI.

The first series of measurements had led to the conclusion that:

> Cane-sugar, dissolved in water, exerts an osmotic pressure equal to that which it would exert if it were gasified at the same temperature and the volume of the gas were reduced to that of the solvent in the pure state. In other words, dissolved cane sugar exerts an osmotic pressure throughout the larger volume of the solution equal to that which, as a gas, it would exert if confined to the smaller volume of the pure solvent.

It appeared important that this conclusion should be tested with the utmost care, and great pains were taken to minimize or remove all known sources of error. The measures which were employed with this end in view have been fully discussed in the two published papers already referred to. A tabular statement of the results is given on the next page.

They appear to confirm in a convincing manner the conclusion which was deduced from our earlier measurements of the osmotic pressure of cane-sugar solutions.

The measurement of the pressure of glucose solutions has also been undertaken, and the first series of determinations is nearly completed. The results indicate that the rule established for solutions of cane-sugar holds equally

well for those of glucose. The measurement of the pressure of glucose solutions was delayed somewhat by a persistent infection of the solutions and membranes with penicillium. This necessitated a search for a poison for the fungus which should be effective in such small quantities that the pressure of the solutions would not be sensibly altered by its presence, and which would not act injuriously upon the membranes. *Thymol* was found to fulfill these conditions in a satisfactory manner.

A Final Summary of Results.

Weight-normal concentration.	No. of experiment.	Temperature of solution.	Observed osmotic pressure.	Theoretical gas pressure at same temperature.	Differences between osmotic and gas pressure.	Molecular weight calculated from osmotic pressure.	Mean molecular weight for each concentration.
			Atmospheres.	*Atmospheres.*	*Atmosphere.*		
0.1	1	24.05°	2.51	2.42	+0.09	327.85	.....
	2	24.23	2.55	2.43	+0.12	322.56	325.21
0.2	1	20.90	4.72	4.79	—0.07	344.96	......
	2	21.47	4.78	4.80	—0.02	340.90	......
	3	21.75	4.81	4.81	0.00	339.74	341.87
0.3	1	21.65	7.24	7.21	+0.03	338.37	......
	2	19.90	7.20	7.16	+0.04	338.20	338.29
0.4	1	21.62	9.64	9.61	+0.03	338.73	......
	2	22.15	9.69	9.63	+0.06	337.50	338.12
0.5	1	22.60	12.06	12.06	0.00	339.59	.....
	2	23.70	12.22	12.10	+0.12	336.19	337.89
0.6	1	24.35	14.74	14.55	+0.19	335.32	......
	2	24.23	14.70	14.55	+0.15	336.07	......
	3	24.1	14.77	14.54	+0.23	334.32	335.24
0.7	1	23.68	16.95	16.94	—0.01	339.59	......
	2	24.03	16.96	16.93	+0.03	339.50	339.55
0.8	1	23.59	19.30	19.35	—0.05	340.48	... ..
	2	23.68	19.39	19.36	+0.03	339.08	339.78
0.9	1	24.78	21.82	21.86	—0.04	340.19	......
	2	24.78	21.91	21.86	+0.05	338.82	339.51
1.0	1	23.58	24.42	24.19	+0.23	336.39	.....
	2	24 55	24.05	24.28	—0.23	342.72	339.56

Simultaneously with the work indicated above, careful determinations have been made of the freezing-points, and the densities at different temperatures, of cane-sugar and glucose solutions, with a view to discovery, if possible, what relations exist between the osmotic pressure of these solutions and their other properties. It had been found, during the earlier work, that if the factor of density is taken into account, the so-called abnormality of the freezing-points of concentrated solutions of cane-sugar disappears, in the sense that all concentrations then conform to the same rule, making it practicable, in the case of cane-sugar, to calculate correctly the freezing-point depression of any solution from its known osmotic pressure, and vice versa. The existence of this relation has been confirmed, but its significance has not been explained.

The work now in progress is as follows: (1) A second series of measurements of the osmotic pressure of glucose; (2) a determination of the pressure of solutions of lactose; and (3) a determination of the osmotic pressure of cane-sugar solutions in the vicinity of 0°.

The second problem has a special interest in connection with the molecule of water of crystallization which is contained by lactose, the question being whether, in solution, this water will or will not be found to play the part of solvent.

The determination of the pressure of cane-sugar solutions at low temperatures may be expected to furnish some evidence as to the validity of the usual explanation of the abnormal freezing-points of such solutions; for if, as supposed, the sugar appropriates a portion of the solvent, thus bringing about a concentration of the solution, we may expect to obtain abnormally high osmotic pressures at temperatures in the neighborhood of the freezing-points.

In the work upon osmotic pressure there have been associated with the author during the past year Dr. J. C. W. Frazer and Messrs. P. B. Dunbar, E. J. Hoffman, B. S. Hopkins, W. L. Kennon, and B. F. Lovelace.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 325. Researches upon (1) *Electrical conductivity of aqueous solutions at high temperatures;* (2) *Electrical transference determinations in aqueous solutions.* (For previous reports see Year Book No. 2, p. XXXI; Year Book No. 3, p. 109, and Year Book No. 4, p. 154.)
$2,000.

These researches have been continued during the past year in the Research Laboratory of Physical Chemistry of the Massachusetts Institute of Technology. The first has been executed with the assistance of Mr. Arthur C. Melcher, Mr. Guy W. Eastman, and Mr. Robert B. Sosman, and the second with that of Mr. Edward W. Washburn. A series of twelve articles, which describe fully the methods and results, has been submitted to the Carnegie Institution of Washington for publication and is now in press. As the general results obtained are fully and concisely presented in the closing pages of that publication, a brief reference to the new experiments will here suffice.

During the past year the work done upon the electrical conductivity of aqueous solutions at high temperatures has consisted in an extension of the measurements previously made with various salts to certain strong acids, namely, nitric, hydrochloric, sulphuric, and phosphoric acids at temperatures up to 306°.

The research previously referred to on the ionization of weak acids and bases and the hydrolysis of their salts has been continued by measuring the conductivity of ammonium hydroxide and acetic acid and studying the

hydrolysis of ammonium acetate at a temperature of 306° by the method described in preceding reports, which consists in determining the increase produced in the conductivity of the salt by the addition to it of one of its hydrolytic products, acetic acid or ammonium hydroxide. From these results the ionization of water at 306° has been derived. An entirely similar investigation of the magnitude of this ionization at ordinary temperatures has also been completed by Mr. C. W. Kanolt, and has yielded results in good agreement with those previously obtained by entirely independent methods. Finally, good progress has been made in the development of the new apparatus for extending the conductivity measurement up through the critical temperature; and also in the development of the method for determining the hydration of ions by transference experiments, but final results have not yet been obtained.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grant No. 326. *Investigation of the values of atomic weights, etc.* (For previous reports see Year Book No. 2, p. XXXII; Year Book No. 3, p. 112, and Year Book No. 4, p. 155.) $2,500.

Abstract of Report.—The full records of two of the investigations described in the last report have been published as Publications of the Carnegie Institution of Washington, Nos. 56 and 61, occupying 68 and 43 pages respectively. These are entitled "Energy changes involved in the dilution of zinc and cadmium amalgams" and "The electromotive force of iron under varying conditions and of its occluded hydrogen." The other investigations outlined in that report which have not already been published are now being prepared for publication.

The following investigations were wholly or partially supported by grants from the Institution.

(1) A revision of the atomic weight of potassium by the analysis of potassium chloride was carried out with the assistance of Dr. Arthur Staehler, assistant in the First Chemical Institute of the University of Berlin, on leave of absence for a year of study in Harvard University. This research was modeled essentially on the lines of that upon sodium. (Publication of the Carnegie Institution of Washington No. 28.) Great care was taken in the preparation of the material and the analysis. The results were as concordant and convincing in this new research as in the previous one, and uncovered as before small errors in the work of Stas. The molecular weight of potassic chloride was referred to the weight of silver just needed to precipitate its chlorine, as well as to the weight of silver chloride. The two methods gave essentially the same result, the former giving $K = 39.114$, and the latter $K = 39.113$, if $Cl = 35.473$ and $Ag = 107.930$. The close agreement of the results confirms the previous Harvard work upon chlorine. (Publication of the Carnegie Institution of Washington No. 28.)

Parallel with this, and supporting its conclusions, there was conducted:

(2) A revision of the atomic weight of potassium by the analysis of potassic bromide, carried out with the assistance of Edward Mueller. This problem involved a number of new points, because the preparation of potassic bromide in a pure state involves many difficulties. The electrolysis of potassic oxalate with a mercury cathode and the subsequent electrical decomposition of the resulting amalgam was found to be one of the most convenient means of obtaining pure potassic hydroxide used in making the bromide. The results confirmed the work with the chloride in a satisfactory manner, giving K = 39.1143 by reference to silver, and 39.1135 by reference to argentic bromide. The average 39.114 of the essentially identical results of the previously described investigation and this one may be accepted as representing very closely the true atomic weight of potassium, if silver is taken as 107.930.

As a contribution towards the determination of the true value for silver, the following investigation also was successfully brought to completion with the assistance of Dr. G. S. Forbes:

(3) The synthesis of argentic nitrate. Here again great care was used in every stage of the work. The employment of vessels of fused quartz and other precautions too numerous to mention carried the work to an unusual degree of accuracy. The essentially identical results showed that if silver is taken as 107.930, nitrogen can hardly be lower than 14.037; or if nitrogen is taken as 14.008, silver can hardly be higher than 107.88. Another somewhat similar research was:

(4) A new determination of the atomic weight of sulphur, carried out with the assistance of Grinnell Jones. Recent investigations, carried out under the auspices of the Carnegie Institution of Washington, have given such definite knowledge concerning argentic chloride that the conversion of the sulphate into the chloride promised to yield trustworthy data for computing the atomic weight of sulphur. It was found that the former salt is completely converted into the latter by gentle ignition in a current of hydrochloric acid gas; and very careful experiments conducted in quartz vessels indicated that the ratio of the equivalent weights is 100.000 : 91.933. Hence, if silver is taken as 107.93 and argentic chloride as 143.403, sulphur must be 32.113, a much higher figure than that usually accepted (32.06); and even if silver is as low as 107.89, sulphur must be almost 32.08. This outcome was not a surprise, for it had been clear that impurities in Stas's silver might have affected his results concerning sulphur as well as his work with chlorine. A single research is not enough to furnish conclusive results in a case of this kind, and the study of the atomic weight of sulphur will be continued.

In addition to these finished researches, other work of the same type was begun, which had as its object the final decision of the uncertainty concern-

ing the atomic weight of silver; but this is not as yet far enough advanced for discussion here. This also will be continued in the near future.

Turning now to the second subject covered by the grant, namely, experimental chemical energetics, there are four other researches to report, as follows: First among these may be mentioned—

(5) A comparison of the compressibilities, surface tensions, specific gravities, vapor tensions, and heats of vaporization of certain organic compounds, carried out with the assistance of J. H. Mathews. Nearly all the data involved in this comparison were determined anew, with carefully prepared material and new and improved apparatus. Thirty-five typical substances were investigated. The investigation was undertaken with the hope of obtaining new light upon the nature of cohesion and its relation to the so-called chemical affinity, and this hope was not wholly unwarranted. The results, in so far as they are capable of interpretation, support the hypothesis of compressible atoms. Both data and conclusions are too voluminous to find a place here. The work upon heat of vaporization was not wholly finished; it will be continued next year. The remainder of the work is almost ready for publication.

The investigation next described dealt with an allied subject:

(6) The compressibilities of various inorganic solids and liquids. It was carried out with the assistance of F. N. Brink. This work was a continuation and amplification of the work of W. N. Stull mentioned in the last report. Other elements and simple compounds were studied, and much time was spent in obtaining a new absolute measurement of the compressibility of mercury, which serves as the standard for other substances.

Three years ago, in an attempt to discover the reason for the difference between the free energy change and the total energy change of a given reaction, the author suggested that this difference might be partly due to the difference in total heat contents between the factors and products of the reaction. With the assistance of F. G. Jackson this hypothesis was submitted to preliminary experimental trial in the research next to be reported, to which may be given the title—

(7) Bound energy and change of heat capacity. In order to obtain significant results it was necessary to evaluate the heat capacities of both the factors and the products of a reversible reaction between the absolute zero and ordinary temperatures. With the help of the admirable liquid-air plant of the Chemical Laboratory of Harvard College results at very low temperatures were obtained, which showed such a well-marked linear tendency that extrapolation to the absolute zero was reasonably safe. The factors and products of three reversible galvanic cells were studied, and in each case it was found that the heat expelled by diminution of the heat contents of the system was of the same order and the same sign as the

difference between the change of total energy and the change of free energy. This result, while not enough to prove the relation in question, is at least highly encouraging, and points to the advisability of continuing the research. Even if the supposed relation should be found to be non-existent, the data are interesting and valuable, and can not but be of use in the experimental development of chemical thermodynamics. The work will soon be continued here.

(8) The adiabatic combustion of organic substances and the heat of complete combustion of benzol formed the subject of another research carried out with the assistance of Dr. L. J. Henderson and H. L. Frevert. In this series of experiments, the last to be reported here, a research begun with a subsidy from the Rumford fund of the American Academy of Arts and Sciences was continued under the auspices of the Carnegie Institution of Washington. The object of the research was the exact determination of the heats of combustion of a series of typical organic substances in order to discover a possible relation between changes of internal energy and differences of structure. The Berthelot-Atwater calorimetric bomb was used adiabatically, according to the new method devised by the author, and various precautions necessary to attain great accuracy were adopted. While the results concerning benzol seem to be definitive, much remains to be done with other substances; hence this investigation is still in progress.

The effort will be made to publish in full the details as soon as possible.

ECONOMICS AND SOCIOLOGY.

REPORT OF THE DIRECTOR OF THE DEPARTMENT.*

BY CARROLL D. WRIGHT.

The year just closing has been a very busy one for the members of this department and those engaged in assisting the work of original research. The total number of persons, including the collaborators, employed in such research work is 135, a large proportion of whom are compensated by the payment of their expenses and the privilege of publishing theses, monographs, etc., acknowledging the aid of the Carnegie Institution of Washington, as provided for in the original plan of the work of this department.

A new division has been added, making twelve in all, and this is entitled "The negro in slavery and freedom." The work in this department is being conducted by Alfred Holt Stone, an educated business man from Mississippi, who is a thorough, impartial, and very candid student of the economic development growing out of negro slavery and the work of the negro under conditions of freedom. The general scope or syllabus of the new work will be outlined in its proper place.

In all the divisions a vast quantity of material has been gathered, and as the investigation goes on the sources of original information develop, and of course the work of collection increases. The prospects of beginning the editorial work—that is, of bringing the amount of material collected together in consecutive volumes—has already been entered upon, but will be prosecuted more particularly during the coming calendar year. I see no reason why the work as originally planned can not be completed for the appropriations made and to be made, although the time may be longer than we at first anticipated. This is quite natural under all conditions, but the financial side is easily cared for by the fact that surpluses accumulate, so as to allow us to use the time without further appropriation than that contemplated.

The Department found it necessary to take up quite an exhaustive index of State documents. This is something which has never been undertaken before, and the work is now going on with vigor. Each State will have an index of its State documents relating to economic and financial affairs, and some others, and the recommendation of the executive committee that an appropriation of $17,500 be made by the Board of Trustees and added to the appropriations already made for the Department of Economics and Sociology, to be used only in case the original appropriations are not sufficient, is a very wise one, and one which I hope will be adopted by the Board of Trustees. Of course, if the regular appropriations of this department are sufficient to

* For the year ending September 30, 1906. Grant No. 311. $30,000 for investigations relative to an economic history of the United States. (For previous reports see Year Book No. 3, pp. 55–64, and Year Book No. 4, pp. 160–169.)

carry out the work of the index, it is very desirable that this should be done, but in order to assure the success of the index it is essential that the Board pledge itself to this plan.

The collaborators in charge of the various divisions have made quite full reports of their work, and I submit a condensed statement relating to each division.

Division 1.—Population and Immigration.

Dr. Walter F. Willcox, in charge, reports that during the past year he has written two articles called out by his work in this field, one on "The expansion of Europe and its influence on population," published by Houghton, Mifflin & Company, in a volume of "Studies in philosophy and psychology;" the other, on "The distribution of immigrants," published in the August issue of the Quarterly Journal of Economics. These have not been written with the aid of Carnegie funds, but have grown out of that work, and are, therefore, useful in the completed work of the Department of Economics and Sociology.

Mr. E. A. Goldenweiser has published an article entitled "Economic condition of the Jews in Russia," being an abstract of a recent two-volume work published in Russia by the Jewish Colonization Society. This has not been done with the aid of Carnegie funds, but has been one of the works growing out of the influence of our own investigations.

Dr. Willcox's work under the above title is being carried on with a proper spirit and an appreciation of the work.

Division 2.—Agriculture and Forestry, Including Public Domain and Irrigation.

This interesting division is under the charge of President Kenyon L. Butterfield, of the Massachusetts Agricultural College. Prof. F. W. Blackmar is aiding President Butterfield, and has in preparation a number of monographs, and also his final report on some of the subdivisions.

There have also been published under this division "Church federation as a practical proposition" (Christian Advocate, March and April, 1906); "The need of church federation in Vermont" (The Congregationalist and Christian World, April, 1906); "The country church and its social problem" (The Outlook, August, 1906). The titles of these short articles seem to be foreign to the work of the division, but they are practically the outcome of studies relating to the farm and social and religious problems. The above are by George Frederick Wells, B. S., Madison, New Jersey.

There has also been published, under President Butterfield's charge, "The economics of land tenure in Georgia" (The Columbia University Press, 1905; Enoch Marvin Banks, of Georgia).

This division perhaps offers as complicated work as any. The ramifications of agricultural topics are somewhat bewildering, but I think President Butterfield is working along proper lines, and will be able to present a very concrete and valuable report.

Division 3.—Mining.

No publication of results has as yet been made in this department, which is under the charge of Edward W. Parker, of the Geological Survey, but he has several chapters of his final work nearing completion, and has no concern about the ultimate result.

Division 4.—Manufactures.

Dr. Victor S. Clark is making a very thorough study of the development of manufactures, and is receiving most cordial responses from all parties, both north and south. The work in this department was delayed by the resignation of Mr. S. N. D. North, on account of his arduous duties in the Census Office, and the whole work of the division turned over to myself. I have employed Dr. Clark as my assistant in this, and I think the division has made advances nearly equal to those of any other. The work is progressing rapidly and satisfactorily.

Division 5.—Transportation.

Prof. B. H. Meyer is conducting this particular work, and is making rapid headway. The only papers which have received financial assistance from the Department in their preparation, and which have thus far been published, are the essays of Professors Ripley and Phillips, but the following works, in all probability, will be finished during the next six or eight months:

"Railway pools," by Alton D. Adams. A good-sized monograph, ready for the printer.
"The Granger movement," by S. J. Buck.
A series of five monographs embracing such topics as "Railway construction," "Financiering," "Receiverships," etc., by Dr. F. A. Cleveland, New York City.
"Railway accidents," by Prof. C. W. Doten, Boston, Mass., whose work has been published since the report of the collaborator in charge was made.
"Early transportation in Ohio," by W. F. Gephart.
"A congressional history of railways," by Dr. Lewis H. Haney, one volume of which is ready for the press.
"Canals," by Chester Lloyd Jones, of Philadelphia, ready for the press.
"The struggle between Atlantic seaports for trade from the interior," by Dr. G. D. Luertscher.
"The relation between Canadian railways and the railways in the United States," by Prof. S. J. McLean.
"Railway development in Southern territory," by Prof. U. B. Phillips, of the University of Wisconsin, published in the Quarterly Journal of Economics, May, 1906, and two other chapters by him, ready for the press.
"The history of railway transportation in Texas," by Prof. C. S. Potts, Austin, Texas.
"Rate systems of trunk lines and southern territory," by Prof. W. Z. Ripley. The first part of his work was published in the Quarterly Journal of Economics last February.
"Commerce on the Great Lakes," by Dr. G. G. Tunnell, Chicago.
"River transportation in the United States," by Dr. R. B. Way, Northwestern University, Evanston, Illinois.
"Railway transportation in the Oregon country," by Prof. F. G. Young, University of Oregon.

It will thus be seen that the Division of Transportation has already completed a great deal of its work.

Division 6.—Domestic and Foreign Commerce.

This division, Prof. E. R. Johnson in charge, has published a number of works, as follows:

"The Consular Service of the United States; its history and activities," by Chester Lloyd Jones, in publications of the University of Pennsylvania, June, 1906.
"The organization of ocean commerce," by J. Russell Smith, in the same publications, May, 1905.
"The American system of improving and administering commercial facilities," by J. Bruce Byall (Annals of the American Academy of Political and Social Science, November, 1904.)
"The British system of improving and administering ports and terminal facilities," by J. Russell Smith, in the same publication.
"Relation of the Government in Germany to the promotion of commerce," by S. Huebner, University of Pennsylvania, in same publication.
"The development and present status of marine insurance in the United States," by same author, in same publication, September, 1905.
"Federal supervision and regulation of insurance," by same author, in same publication, November, 1905.
"Ocean and inland water transportation," by Prof. Emory R. Johnson, in charge of the division, published by D. Appleton & Co., June, 1906.

These works have been aided rather than paid for by grants from the Carnegie Institution. Mr. A. A. Giessecke, of Philadelphia, and Dr. Walter Sheldon Tower, University of Pennsylvania, have done a great deal of work, as has Prof. Raymond McFarland, of Massachusetts, but their work is not ready for publication.

Division 7.—Money and Banking.

No publications have as yet been issued by this division, of which Prof. D. R. Dewey is in charge, but a vast deal of work is under way. There has been some difficulty in the prosecution of the work of this particular division on account of the lack of available men willing to take it up on the basis proposed by the department in the initiative. New men are being found, however, and the work is progressing, more than double the amount noted in last year's report now being under way.

Division 8.—Labor Movement.

Dr. Carroll D. Wright is in charge of this division. An extensive work, subsidized in a measure, by the Department of Economics and Sociology has been brought out under the editorial charge of Jacob H. Hollander, entitled "Studies in American trade unionism." This work will be of very great value when the final volumes under the labor movement are brought into shape. Further investigations are being made under Dr. Hollander's charge, the larger part of the expense being borne by others.

There has also been published "The history of the industrial employment of women in the United States," by Miss Edith Abbott. This work appeared in the Journal of Political Economy for October, 1906, and is an exceedingly valuable contribution to the completed work. Miss Abbott, aided by Miss

Breckenridge, of the University of Chicago, is at work upon other matters germane to the subject.

An epitomized digest of the labor laws of the United States is also available, with the exception of bringing the matter down to the latest date. A great deal of original material is being brought to light relative to the earlier labor movement in the United States and its influence upon economic development. Also the conditions and progress of labor in the South in antebellum times. Very many subjects relating to this division have already been treated in documents and volumes, and are available for the final work.

Division 9.—Industrial Organization.

Prof. J. W. Jenks, in charge, reports that no publication has yet been made under his division requiring aid from the Carnegie funds. It has seemed best to him to spend the time largely in digesting material under his immediate supervision rather than the preparing of monographs; but he has a great deal of work well under way, the items of which have already been reported during the past month to the executive committee.

Division 10.—Social Legislation.

Under Prof. Henry W. Farnam's direction the following monographs have been published:

"Trade unions and the law in New York," by George Gorham Groat, Ph.D., in the Columbia University Studies.

"History of labor legislation in New York," publications of the American Economic Association, 1905, by Fred R. Fairchild, Ph.D., Yale University.

Two studies have been completed during the past year, but not yet published—one by Dr. Alba M. Edwards, on the labor legislation of Connecticut, the other by Dr. J. L. Barnard, on the labor legislation of Pennsylvania. Work is also being prosecuted on the social legislation of the Southern States, the labor legislation of Illinois, and the pauper legislation of Ohio. Professor Farnam has made plans, in connection with the Wisconsin Free Library Commission, for extended work during the coming year in the Middle States. He proposes to give the history of labor legislation in a few States—not all the States in the Union, but enough to indicate the progress which has been made.

Division 11.—Federal and State Finance, Including Taxation.

Prof. H. B. Gardner, in charge of the division, reports that the results of his extensive inquiries are beginning to come in, but nothing has as yet been published. He expects, however, that some papers or monographs will be published during the year 1907.

Division 12.—The Negro in Slavery and Freedom.

After very serious consideration and much discussion the collaborators, at their meeting in May last, brought to conclusive arrangements the suggestions

which had been discussed at previous conferences, and the title of the work was given as above, "The negro in slavery and freedom."

Of course not much has been done under this division on account of its recent constitution, but Mr. Stone has outlined a treatment which is reasonably exhaustive relating to the economic life of the American negro, without, however, trespassing on either the political or social aspects of the topics. In his syllabus he says the difficulty of treating the one as separated from the other two is frankly recognized, but the desirability of such a method is believed to more than outweigh the difficulties involved in its execution. Mr. Stone will make an effort to interpret the salient features of negro life in relation to their economic significance, both to the race and to the country as a whole, the purpose being to correlate the negro's economic history with that of the American people along certain broad lines, as, for example, through the cotton industry and in the creation of national wealth and favorable trade balances as affected by products closely identified with negro labor. Mr. Stone will treat of the condition of laboring classes during the American colonial period—the introduction of negro slavery into America as an economic factor. He will also investigate the efforts to utilize slave labor in manufacturing and other industrial enterprises. His work, if carried out fairly well, will constitute an exceedingly important and novel feature in American economic history. He will also treat of the negro as a free man, the rise and development of the negro industrial schools, their effect with reference to local economic conditions, the negro landowner, and all such topics as will bring out clearly and fully the whole industrial relation of the negro to economic conditions.

It will thus be seen that the Department of Economics and Sociology is progressing in its work as rapidly as can be expected with reference to good results. As I have stated in previous reports, the really important mission of the Department is to secure a great collection of materials which will be available to the historian not only of economic development, but to others. The Department does not aim so much to write a literary history on economic development as to put the matter before the people in a way so much needed at the present time.

ENGINEERING.

Durand, F. W., Stanford University, California. Grant No. 64. *Experiments on ship resistance and propulsion.* (For previous reports see Year Book No. 2, p. XXXII; Year Book No. 3, p. 113, and Year Book No. 4, p. 170.) $4,120.

Professor Durand reports that his researches are practically finished and he is engaged in preparing a final report to the Institution. A preliminary report on "Experimental researches on the performance of screw propellers" was published in the fall of 1905 in the Transactions of the Society of Naval Architects and Marine Engineers.

Goss, W. F. M., Purdue University, Lafayette, Indiana. Grant No. 114. *Research on the determination of the value of high steam pressures in locomotive service.* (For previous reports see Year Book No. 3, p. 114, and Year Book No. 4, p. 170.) $5,000.

Professor Goss summarizes the results of his study concerning the value of high steam pressures in locomotive service, the details of which will be presented in Publication No. 66 of the Carnegie Institution of Washington, as follows:

(1) The results apply only to practice involving single-expansion locomotives using saturated steam. Pressures specified are to be accepted as running pressures. They are not necessarily those at which safety valves open.

(2) Tests have been made to determine the performance of a typical locomotive when operating under a variety of conditions with reference to speed, power, and steam pressure. The results of 100 such tests have been made of record.

(3) The steam consumption under normal conditions of running has been established as shown in Table 1.

(4) The results show that the higher the pressure, the smaller the possible gain resulting from a given increment of pressure. An increase of pressure from 160 to 200 pounds results in a saving of 1.1 pounds of steam per horse-power hour, while a similar change from 200 pounds to 240 pounds improves the performance only to the extent of .8 of a pound per horse-power hour.

(5) The coal consumption under normal conditions of running has been established as shown in Table 2.

(6) An increase of pressure from 160 to 200 pounds results in a saving of 0.13 pound of coal per horse-power hour, while a similar change from 200 to 240 pounds results in a saving of but 0.09 pound.

(7) Under service conditions, the improvement in performance with increase of pressure will depend upon the degree of perfection attending the

maintenance of the locomotive. The values quoted in the preceding paragraphs assume a high order of maintenance. If this is lacking, it may easily happen that the saving which is anticipated through the adoption of higher pressures will entirely disappear.

(8) The difficulties to be met in the maintenance both of boiler and cylinders increase with increase of pressure.

(9) The results supply an accurate measure by which to determine the advantage of increasing the capacity of a boiler. For the development of a given power, any increase in boiler capacity brings its return in improved performance without adding to the cost of maintenance or opening any new avenues for incidental losses. As a means to improvement, it is more certain than that which is offered by increase of pressure.

Boiler pressure.	Steam per horsepower hour.
120	29.1
140	27.7
160	26.6
180	26.0
200	25.5
220	25.1
240	24.7

TABLE 1.

Boiler pressure.	Coal per horsepower hour.
120	3.84
140	3.67
160	3.53
180	3.46
200	3.40
220	3.35
240	3.31

TABLE 2.

(10) As the scale of pressure is ascended an opportunity to further increase the weight of a locomotive should in many cases find expression in the design of a boiler of increased capacity rather than in one for higher pressures.

(11) Assuming 180 pounds pressure to be accepted as standard, and assuming the maintenance to be of the highest order, it will be found good practice to utilize any allowable increase in weight by providing a larger boiler rather than by providing a stronger boiler to permit higher pressures.

(12) Wherever the maintenance is not of the highest order the standard running pressure should be below 180 pounds.

(13) Wherever the water which must be used in boilers contains foaming or scale-making admixtures, best results are likely to be secured by fixing the running pressure below the limit of 180 pounds.

(14) A simple locomotive using saturated steam will render good and efficient service when the running pressure is as low as 160 pounds. Under most favorable conditions no argument is to be found in the economic performance of a machine which can justify the use of pressures greater than 200 pounds.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. Grant No. 241. *Study of fundamental problems of geology.* (For previous reports see Year Book No. 2, pp. 261–270; Year Book No. 3, pp. 195–258, and Year Book No. 4, pp. 171–190.) $6,000.

The work of Dr. Chamberlin and his collaborators during the past year followed essentially the lines set forth in previous reports. The personal studies of Dr. Chamberlin were rather widely distributed over the group of cosmogonic and geologic problems outlined in the report of last year, but embraced some special studies on the former rates of rotation of the earth, on the reversal of deep-sea circulation, and on the fourfold organization of typical atmospheres. The special nature of these is, in a measure, indicated in the synopses of his papers given below.

Prof. F. R. Moulton continued his computations of the orbits of materials ejected from one sun under the differential attraction of a second sun passing near it, the endeavor being to test mathematically the working value of some of the more basal propositions of the hypothesis that spiral nebulæ have arisen from the ejections and perturbations attendant upon stellar approaches. These computations were carried forward continuously during the whole year. Forty-eight cases, in addition to those reported last year, were mathematically treated. The courses of the orbits were followed by computation for an average period of about five years. The perturbations were found so great that it was necessary to use short intervals in most of the computations, and this entailed very large amounts of numerical work in which Mr. Elton James Moulton assisted. Most of the cases selected were such that the disturbing sun at its nearest approach to the disturbed sun was still at a distance of five astronomical units. In eight of the cases the orbits of the two suns were hyperbolas with an eccentricity of 1.2. A sufficient number of cases have now been worked out to give a fair basis for general treatment and provisional deductions. It appears already that in a considerable percentage of assignable cases the ejected material will be left by the disturbing sun revolving in orbits whose eccentricities are of the same general magnitude as those of many of the planetoids.

Dr. A. C. Lunn continued his mathematical inquiries into the application of geophysical theory to accretion under the planetesimal hypothesis, particularly in its relations to the temperatures and other physical states of the earth's interior. Following his treatment of a theory initiated by Fisher—but worked out by Dr. Lunn on the basis of the Laplacian law of density—and the application of the results under alternative secondary postulates, which was essentially completed last year, he entered upon a study of the effects of changes in the secondary hypotheses thus entertained, and upon a critical examination of them. The previous inquiry was traversed by the

substitution of Roche's formula of internal density and by other formulas deduced to satisfy special conditions. A contrasting theory was also developed on the basis of a substance whose nature was such that the work of compression was done mainly against volume-elasticity, and deductions from this compared with those previously obtained. The special phases of these treatments will be best understood from the synopsis of his report given below.

Dr. Julius Stieglitz determined mathematically the relations of equilibrium subsisting, under varying degrees of concentration, between the carbon dioxide of the atmosphere and calcium sulphate and calcium carbonate and bicarbonate in solution in water in contact with the atmosphere. This involves the conditions of precipitation of the calcium salts. Variations of carbon dioxide from ten times greater to ten times less than the present atmospheric content were employed. The rigorous calculations have been restricted for the present to the simple case of the three calcium salts being present alone in aqueous solutions, and proximate calculations have been made to determine roughly the influence on the conditions of equilibrium of the presence of sulphates other than gypsum in the proportions existing in the ocean at present. The purpose of the inquiry was to lay a foundation for the study of such states of equilibrium between the atmosphere and the hydrosphere as may be involved in climatic problems on the one hand, and in the determination of the saline content of the hydrosphere, and of the nature and order of its precipitations, on the other.

The researches of this group of colaborers and the relations of these results to one another are more concretely expressed in the following synopses of their papers, which are now in an advanced stage of preparation and are soon to be submitted as a correlated group of mutually auxiliary discussions, under the title given below.

CONTRIBUTIONS TO COSMOGONY AND THE FUNDAMENTAL PROBLEMS OF GEOLOGY, I.

PAPER I.—*On the Planetesimal Factor in Cosmogony.* By T. C. CHAMBERLIN.

This opens with a critique upon the basal deductions usually drawn from the direction of planetary rotation relative to the state of the parent nebular material and currently accepted during the past century. The doctrine that the aggregation of dispersed nebulous matter pursuing independent orbits, and controlled by Kepler's third law, would normally give rise to retrograde revolutions of the planets is challenged, and arguments for the reversal of the proposition are presented. It is pointed out that the rectification of this proposition is fundamental in that, in the currently accepted form, it is a serious bar to the acceptance of any hypothesis founded on a revolutionary state of the parent nebular matter so far as applied to the solar system, while the truth of the reverse proposition is prerequisite to the

tenability of any hypothesis of the planetesimal order. The possible sources of planetesimal organization are then discussed. Four states of organization of free molecules are found to be required by a rigorous application of the kinetic theory of gases to gaseous spheroids and to atmospheres, the first being the familiar collisional or truly gaseous state; the second, the state of the elliptical, or fountain-like movement of molecules above the collisional spheroid recognized by Stoney; the third, a system of molecules in quaquaversal revolutions around the collisional spheroid, and the fourth, a planetesimal system surrounding the equatorial tract of the collisional spheroid when in rotation. The distribution of these is discussed and their relations of equilibrium with one another, together with the application of these equilibria to varying stages of evolution. In their application to the evolution of contracting gaseous spheroids, it is shown that the centrifugal component of revolution at the equator can rarely, if ever, become equivalent to the centripetal acceleration of gravity, as the result of simple contraction, but that previous to reaching that stage the molecules of the collisional spheroid must pass into the three other systems of organization. The paper contains an ampler statement of the planetesimal hypothesis than has been previously published, with new discussions of certain points, among which are the significance of the present slow rotation of the sun, and of the obliquity of its axis, out of which springs a suggestion relative to the possible origin of binary stars. In the disposal of the ancestral planetary family of the sun is found a possible origin of comets and meteorites.

PAPER II.—*On the Probability of a Near Approach of two Suns and on the Orbits of Material Ejected from them under the Stimulus of their Mutual Tidal Disturbances* By F. R. MOULTON.

The treatment of the first part of the theme consists of the determination, so far as the imperfect data will permit, of the probability of the near approach of two suns. In the treatment of the second part, after some considerations relative to the nature of the tidal disturbances, the perturbations produced by one of the two bodies upon the material ejected from the other are considered at length mathematically. The results of the computations of the paths of the ejected material in the cases selected are given, and are illustrated by plottings. Forty-eight such cases in which varying assumptions are made relative to the positions, paths, and sizes of the two suns are treated. The aggregate period through which the computations of perturbations extend exceeds 200 years. Such general deductions are drawn as the nature and number of cases investigated warrant. Among these is the conclusion that in many cases the ejected material is left by the disturbing sun, when it has receded to an ineffective distance, moving about the parent sun in elliptical orbits whose eccentricities do not exceed some of those found in the orbits of the planetoids.

This paper is in essence a mathematical discussion of the more fundamental factors of the theory that the spiral nebulæ were derived from suns through approach to one another and bears radically upon the planetesimal hypothesis discussed in the preceding and following papers.

PAPER III.—*On the Growth of the Earth by Accretion under the Planetesimal Hypothesis.* By T. C. CHAMBERLIN.

The probable character and limitations of the planetary nuclei, the knots of the spiral nebulæ, are discussed and the mode of aggregation and the associated temperatures considered. Taking the alternative of a primitive atmosphereless earth as the more extreme, the accession of the atmosphere, followed by that of the hydrosphere, is sketched, leading to the discussion of the origin of the ocean basins and the conditions that controlled the evolution of the continents. The development of interior heat by planetesimal impact, by compression, by atomic and molecular union, and by radioactive agencies is discussed, together with a theory of the origin and evolution of vulcanism. The possibility of the early introduction of life is noted and the requisite conditions of light and temperature are treated, involving autogenic as well as solar sources of radiant energy.

PAPER IV.—*On Certain Applications of Geophysical Theory under the Planetesimal Hypothesis, especially those Relating to Compression and Temperature.* By ARTHUR C. LUNN.

This paper is devoted mainly to a quantitative study of that portion of the earth's internal energy which is supposed to have been derived from the mechanical energy of a primitive system of planetesimals subsequently gathered into a planetary mass, and of the transformation of this internal energy into the thermal form during the epoch of accretion, together with a study of its subsequent redistribution by conduction.

In Part I a theory initiated by Fisher is developed on the basis of the Laplacian law of density, together with certain auxiliary assumptions. Formulas and tables are given showing the variation of dimensions and the internal densities of the mass during the epoch of accretion and the differential effect of the accession of an additional stratum on the size and on the moment of inertia of the mass, together with the deformation of the mass elements accompanying the resulting compression. Determinations under alternative secondary postulates of the original distribution of the temperature produced by compression, and of its redistribution by conduction, are found to show the existence of a characteristic zone of rising temperatures during the earliest ages.

Part II is given to an inquiry as to what changes in the results recorded in Part I are produced by changes in the secondary hypotheses employed, and to a critical examination of the latter. The computed masses of the nucleus at various stages of accretion are compared with the observed masses

of the small planets in the solar system. The previous theory is reviewed with the substitution of Roche's formula for the internal variations of density, and, to serve as a basis of comparison, certain other formulas of the distribution of density are deduced to satisfy special conditions. Criticism in the line of general thermal dynamics leads to the suggestion that the theory given is possibly an extreme view applicable to a substance in which the work of compression is mainly frictional.

In Part III a contrasting theory is outlined applicable to the case of a substance whose nature is such that the work of compression is done mainly against volume-elasticity under the assumption that the successive strata deposited at the surface are reduced to uniform entropy by free radiation while their material was exposed. The thermal phenomena arising in this case are compared with those developed under the conditions outlined in Part I.

This paper thus treats mathematically a considerable range of fundamental propositions that enter basally into the problems discussed in the preceding and following papers.

PAPER V.—*On Certain Problems of the Lithosphere.* By T. C. CHAMBERLIN.

This paper is concerned chiefly with the application of the deductions of the preceding papers to the deformation of the lithosphere. It attempts to differentiate deep bodily deformations from those affecting a limited superficial shell. The nature and depth of this superficial shell, its relation to a postulated zone of shearing below and to the more general deformations of the deeper body of the earth on which it is dependent, are discussed. It is assumed that tensional stages of the protuberant portions of the earth follow compressive stages and give rise to a slow glacier-like creep of the unbalanced protrusive portions and to relaxitative movements of the superficial shell. Certain special applications of these deformations are outlined.

PAPER VI.—*On the Former Rates of Rotation of the Earth.* By T. C. CHAMBERLIN.

This theme is discussed here under the belief that it bears vitally on conceptions of the constitution of the earth and on certain modes of deformation, as well as on superficial sea action. The paper opens with a review of the grounds currently assigned for a high primitive rate of rotation based upon cosmogonic hypotheses and on tidal deductions, and it endeavors to show that these may be radically modified by alternative cosmogonic considerations and by alternative interpretations of the nature and value of such tides as affect rotation. The purpose of this introductory review is to free the problem from preoccupying presumptions springing from extra-terrestrial sources and cosmogonic hypotheses and to open the way for the untrammeled application of the geological evidences that bear upon the problem. These are then set forth. The paper is given this place in the series because of its bearings upon problems of deformation.

PAPER VII.—*On the Principal Constants of an Earth-like Body under the Varying Conditions of Changing Rates of Rotation.* By C. S. SLICHTER.

A series of ten rotational stages, ranging from a rotation period of 3.82 hours to the present rate, is made the basis of computation, the results of which constitute the body of the paper. The constants are worked out on the assumption that the internal densities follow Laplace's law. The methods of computation, so far as new, are given. The data of this paper enter fundamentally into the preceding discussion on rotation.

PAPER VIII.—*On Certain Problems of the Hydrosphere and Atmosphere.* By T. C. CHAMBERLIN.

This paper proceeds on the assumption that the climatic problems of the earth center about the discovery and elucidation of a system of automatic control of such efficiency as to have kept the temperature of a large portion of the surface of the earth throughout its organic history within the narrow range of 100° C., and at the same time to have kept the constitution of the atmosphere within the like narrow range consistent with plant and animal life. The paper recurs to the four-fold organization of a typical atmosphere set forth in Paper I, and endeavors to apply the states of equilibrium deduced therefrom to the feeding and depletion of the atmosphere. It is recognized that the hydrosphere is a derivative from the atmosphere, and that its relations of equilibrium with the atmosphere are important factors. The relations of equilibrium between the free atmospheric gases and those absorbed or held in feeble combination in the ocean are considered, together with the conditions and rate of exchange. The discussion of changes in the *basis* of equilibrium forms a vital factor. The function of the ocean as a source of atmospheric storage and supply is discussed and a possible reversal of the deep-sea circulation, alternating with circulation of the present order, is considered as a possible explanation of the alternation of warm polar temperatures with periods of marked glaciation and aridity. The sources of internal supply of atmospheric and hydrospheric material are reviewed and correlated with sources of depletion, so far as practicable. The function of deformation and base-leveling in changing the available amounts of the critical atmospheric constituents is set forth. The relationship of the atmosphere's constituents to thermal absorption, retention, and radiation, and the bearing of these upon the climate, are also treated.

PAPER IX.—*On the Relations of Equilibrium between the Carbon Dioxide of the Atmosphere and Calcium Sulphate and Calcium Carbonate and Bicarbonate in Solutions in Water in Contact with it.* By J. STIEGLITZ.

This paper embraces the results of a computation of the varying equilibria subsisting between different degrees of concentration of carbon dioxide in the atmosphere and varying degrees of concentration of calcium carbonate and bicarbonate, and calcium sulphate in solutions in free contact with the atmos-

phere. It also considers the relative points of saturation of the calcium salts under varying conditions and the consequent order of their precipitation. The computations have been developed with reference to their application to certain of the problems of equilibria set forth in the preceding paper, and also incidentally to the order of deposition of evaporation deposits under conditions of aridity and other atmospheric states. They have been limited for the present to two cases, the first when the three calcium salts are present alone, and the second when they are present with other sulphates, of the nature and quantity found in the ocean at the present time.

PAPER X.—*On a Set of Postulates Relative to the Mega-Physical Constitution of the Earth.* By T. C. CHAMBERLIN.

This is little more than a convenient synoptical arrangement of the deductions, hypotheses, and postulates derived from the planetesimal hypothesis and from other sources, gathered together in brief statement, partly for convenience and partly to give in miniature a revised conception of the earth.

Willis, Bailey, U. S. Geological Survey, Washington, District of Columbia. Second Supplement to Grant No. 116 and Grant No. 373. *Completion of Reports A, B, and C, on geological research in China.* (For previous reports see Year Book No. 2, p. xxxv; Year Book No. 3, p. 118, and Year Book No. 4, pp. 192–203.) $8,250.

The year has been devoted to preparation of publications. Report A has been completed and transmitted to the Institution. It pertains to the geographic and geologic observations in China by Messrs. Willis, Blackwelder, and Sargent, and also includes the contributions on petrography and zoology by Mr. Blackwelder, which were originally intended for Report B. Report B relates to paleontology, and the papers of which it is to be composed are nearly complete. The topographic and geologic atlas authorized under Grants Nos. 261 and 280 is printed. Report C, on systematic geology of China, will be ready for publication before the end of this year, and then the results of Mr. Willis's expedition to China will have been submitted to the Institution in full.

Washington, Henry S., Locust, New Jersey. Grant No. 95. *Chemical investigations of igneous rocks.* (For previous reports see Year Book No. 3, p. 113, and Year Book No. 4, p. 158.) $1,200.

Abstract of report.—After his return from the trip described in his preceding report, Dr. Washington's first occupation was the completion of his paper on the igneous rocks of the central Italian volcanoes. This has appeared as Publication No. 57 of the Carnegie Institution of Washington, under the title of "The Roman Comagmatic Region."

The study of the material collected in Catalonia, Sardinia, Pantelleria, and Linosa was then begun. This was very largely chemical, preceded by

microscopic examination of the thin sections, so as to insure the selection of representative specimens for analysis. The number of analyses so far made of these rocks is twenty-four, with three of minerals occurring in them. The rock analyses are, for the most part, of the more femic types (basalts), with fewer of the more salic ones. This analytical work indicates that the lavas of Catalonia are closely similar to the more femic ones of the other three districts, and discloses the existence in the western Mediterranean basin of a hitherto unrecognized comagmatic region (petrographic province). This forms a volcanic zone extending from Linosa, on the southeast, through Pantelleria and western Sardinia, to Catalonia, the volcanoes of the French Mediterranean littoral (as those of Agde and Montpellier) probably also belonging to it, with a possible extension down the east coast of Spain, and also possibly in Tripoli south of Linosa. The most striking feature of this region is the richness of the more femic rocks in titanium, the figures for TiO_2 found in the analyses being higher than those shown by any other known region of igneous rocks, other than some titaniferous ore bodies produced by magmatic differentiation. It may be mentioned that the figures for TiO_2 in these basalts vary from 2.64 to 6.88 per cent. Other chemical features of the region are the high amounts of iron oxides, especially ferrous, the usually rather low alumina, magnesia, and lime, the dominance of soda over potash, and the prevalence of nickel in, for this constituent, rather large amounts. The analyses which were made of Pantellerian lavas, as well as those of the lavas of Graham's Island, and of that of 1891 in the vicinity, substantiate the earlier ones of Foerstner in their general features, though being more complete they introduce some very important corrections.

The lavas of Catalonia and Linosa were found to be salfemanes without exception, belonging to the subrangs camptonose, limburgose, and monchiquose, or basalts and nephelite-basalts in the prevailing classifications. Those of Sardinia and Pantelleria are much more varied—so much so as to preclude their enumeration here.

The minerals analyzed include an augite and an olivine from Monte Ferru and a hornblende from Linosa. The two former are not specially noteworthy in themselves, though of interest in connection with the rocks in which they occur, but the hornblende is remarkable, the figure for TiO_2 (8.47) being the highest yet recorded for this mineral. It is probably related to the kaersutite of Greenland. A peculiar and possibly new mineral was found in the crevices of rhyolite at Monte Arci, forming yellow, translucent, hexagonal prisms, and will be investigated later.

The study of the material mentioned above will extend probably over two years, and the results will appear from time to time in the American Journal of Science, the Journal of Geology, and probably elsewhere. It is estimated that at least 70 analyses must be made for proper discussion of all the rock types of this region.

In addition to the above investigation, two analyses were made of the well-known syenite of the Plauenscher Grund. These differ widely in some important respects from the earlier ones, and were published in the American Journal of Science (v. XXII, 1906, p. 129), with a description of the type and discussion of its systematic position. Short papers are also being prepared on some rock types from Santorini and Monte Vulture, analyses of which have been made. There is also being written an extended discussion of the chemical conditions controlling the formation of leucite in igneous rocks, which is a theoretical extension of observations made in connection with the study of the leucitic rocks of central Italy.

GEOPHYSICAL RESEARCH.

Adams, Frank D., McGill University, Montreal, Canada. Grant No. 335. *Investigations on the flow of rocks.* (For previous reports see Year Book No. 2, p. XXXIV; Year Book No. 3, p. 119, and Year Book No. 4, pp. 230–231.) $1,500.

The investigation into the elastic constants of rocks, which was undertaken by Professor Adams in conjunction with Dr. E. G. Coker, was completed last October and the results have appeared in Publication No. 46 of the Carnegie Institution of Washington, entitled "An investigation into the elastic constants of rocks, more especially with reference to cubic compressibility." An abstract of this paper was also published in the American Journal of Science for August, 1906.

The attempt to measure the cubic compressibility of rocks by another independent method—that proposed by Messrs. Richards and Stull—was also continued during the past year, and while the experimental difficulties have not as yet been entirely overcome, it is expected that satisfactory measurements will be obtained by its use during the coming year.

The experimental work which has been carried on during the past year consisted chiefly, however, of an elaborate series of measurements of the internal friction developed in rocks when these were subjected to very slow deformation under varying conditions of differential pressure. The investigation was made to cover nine typical rocks, namely:

Alabaster, Castelino, Italy.	Sandstone, Cleveland, Ohio.
Soapstone, Virginia.	Slate, New Richmond, Canada.
White Marble, Carrara, Italy.	Diabase, Sudbury, Canada.
Black Marble, Belgium.	Granite, Baveno, Italy.
White Dolomite, Cockeysville, Maryland.	

Comparative measurements were made with the metals copper and lead. Sixty-six complete determinations of internal friction have been made up to the present date, and the investigation, which will be completed during the coming year, will furnish, it is believed, valuable data bearing upon a number of problems in geophysics.

Simultaneously investigations have been made into the structures developed in the harder plutonic rocks of the earth's crust, as, for instance, diabase, essexite, and granite, by differential movements under conditions of heat and pressure, which reproduce those which there is reason to believe obtain in the earth's crust in the zone of flow. This experimental work forms a continuation of that which has already been carried out with the softer rocks, such as limestones, dolomites, etc.

Becker, George F., U. S. Geological Survey, Washington, District of Columbia. Grant No. 226. *Experiments on elasticity and plasticity of solids.* (For previous reports see Year Book No. 3, p. 80, and Year Book No. 4, pp. 221–223.) $7,500.

During the past year the work on elasticity has been conducted along the two lines indicated in the last report. The first has been a continuation of the tension tests on steel tapes suspended in the Washington Monument. Preliminary observations proved the need of accurate temperature measurements. This was first accomplished by measuring the electrical resistance of copper wires placed inside the closed tube containing the tape. New tapes were procured later, and were calibrated electrically in the laboratory before being put in place. The measurement of electrical resistance by means of a galvanometer and a standard resistance-box affords a simple and sufficiently accurate method of determining the mean temperature of the tape. Incidental to the measurement of temperature, the method also affords a very satisfactory means of investigating the variation of temperature and the variation of electrical resistance with strain, subjects on which existing data are not conclusive. The importance of a thorough investigation of the after-effect curves as a means of elucidating the phenomena of elasticity was emphasized in the last annual report, and the observations made during the year amply justify these conclusions. As was there stated, the complete solution of the problem would consist in determining the after-effect curves, and in particular the asymptotes to these curves, for the various loads. Owing to the limited time for which the use of the Washington Monument had been placed at the disposal of Dr. Becker, he decided to spend about six months of the year in making observations for the complete after-effect curve for small loads (5, 10, and 15 kg.) well within the so-called limit of elasticity. The remainder of the time has been spent in studying elastic fore-strain in a manner quite different from the usual method. A load was applied and allowed to remain about two hours, observations in the meantime being made at fixed intervals of time during the progress of the strain. The load was then removed, and the specimen allowed to rest three or four days for the larger loads, until it had completely regained its initial dimensions, after which a second load was applied, and the observations again made at the same time-intervals after the application of the load as before. This gives

an easy means of comparing the ordinates of the successive after-effect curves at fixed intervals of time, and therefore gives a load-strain relation for each instant at which the observations are made. Successive loads have been applied in this way at intervals of 5 kg. up to and including 50 kg., with satisfactory results. The strains are much larger than those measured heretofore, while the accuracy is the same as that of the best methods. The total number of observations made at the Washington Monument during the year is about 1,350. With the exception of a small correction for the variation of Young's modulus with temperature, the computations have been completed, and the data are ready for publication. Not much attention has been given to the theoretical discussion of the experimental results, and for this reason it is perhaps wise to refrain from stating some apparently obvious but important conclusions that seem to be well established by the experiment.

A second line of work has been to design apparatus to be used in the Physical Laboratory of the United States Geological Survey in studying the variations of Young's modulus for various metals and crystals at high temperatures. The preliminary investigations have been completed. An interferometer for measuring strains has been constructed, and a well-equipped electric furnace will be ready for use in a few weeks. A temporary furnace has also been constructed and used to determine the variations of Young's modulus at temperatures ranging from 25° to 65° C. of the steel tapes which have been used in the experiments at the Washington Monument. This furnace will be used during the year to study the after-effect curves for various loads of certain metals maintained at a constant temperature of about 25° or 30° C.

Some preliminary work has been done on the variation of electrical resistance of a granite containing moisture.

Bibliography of Geophysics.—For report on this subject see under Bibliography, page 45.

Day, Arthur L., U. S. Geological Survey, Washington, District of Columbia. Grant No. 334. *Investigation of mineral solution and fusion under high temperatures and pressures.* (For previous reports see Year Book No. 3, p. 80, and Year Book No. 4, pp. 224–230.) $17,500.

With the work of the present year our studies of mineral fusion and solution in the laboratory may be said to have passed beyond the preliminary stage. It has been found thoroughly practicable to study several of the important problems in mineral formation by applying the principles and methods of physics and physical chemistry at the temperature where the formation actually occurs, and to carry out the quantitative determinations with an accuracy entirely comparable with the more conventional physical and chemical research at ordinary temperatures. It is therefore a great pleasure, at the close of the largest year's work which we have yet undertaken, to be able to express our renewed confidence in these methods and our full expectation that they will soon be generally adopted and applied to build up a quantitative science of mineral solutions which will place our knowledge of the minerals composing the accessible portions of the earth on the same level with the long respected "exact" sciences. In expressing this confidence in the coming development of a quantitative science of petrology, I am not unmindful of the time factor involved. Exact research is slow and the opportunities for it limited; but, on the other hand, I doubt if any extensive field of research was ever entered upon with more certain assurance of a successful future.

The essential novelty of the present plan, when freed from all technical terms and expressions, is this: It has been the habit heretofore, in investigating the makeup of the earth, either to study natural minerals in which, of course, the formation process is already complete and no longer accessible, or to study artificial minerals in the same way after actual formation is over. Our plan has been to transfer the investigation as far as possible to the region where the earth-making processes are at work, and to observe the minerals during actual formation. Only in this way, in my opinion, can we succeed in ascertaining which forces are essential and which are merely incidental to the operations under observation, and in measuring their magnitude. Then only does it become possible to treat mineral solutions at high temperatures substantially like other chemical solutions at lower temperatures, and to utilize the experience gathered by modern chemistry during the last quarter of a century.

The method of actual procedure and the progress so far made can also be outlined in a general way quite briefly. We must begin with the simplest problems, and proceed in an orderly way to those more complicated—first, the properties of single minerals over the entire range of their stable existence (solid and liquid); then combinations of two, in which both remain stable;

then similar combinations in which exceptional phenomena occur; then simple rocks of three components, etc.—the general principle of effective progress being to meet and study the unknown phenomena *one at a time*. Our studies hitherto have, therefore, been confined to single minerals and to comparatively stable combinations of two under usual atmospheric conditions. The modified conditions which may be produced by an atmosphere of carbon dioxide, or water vapor under pressure, or by pressure alone, have been taken up only in certain special cases, and their systematic development is dependent upon more favorable laboratory conditions than those now available.

First of all, a simple type of two-component system in which the components form an isomorphous series of minerals (the plagioclase feldspars) was carefully studied, then a typical eutectic pair (the lime-silica series), in which we found three eutectic mixtures and two intermediate mineral compounds. It was also found possible to discover and locate changes in the crystal form of some of the solid minerals below their melting temperature, even where the heat of transformation was extremely small. Such changes fall into two general classes, one in which the change is reversible and one in which it is not. We have been able to locate successfully a number of cases of the reversible change, and during the past year have encountered and successfully solved a problem in which a mineral compound (magnesium metasilicate) appeared in four different crystal forms in irreversible relation to each other, *i. e.*, three of the forms could be changed into the fourth by heating, but the reverse change does not occur.

This last investigation yielded one fact of a somewhat unusual character. We have been accustomed to think of the laboratory of nature as possessing one great advantage over any effort put forth by man; with nature we have assumed that there must always have been plenty of time for natural processes to go on to completion. And yet we found that the particular form of this magnesium silicate which is common in nature (enstatite) is not the stable form; the process was rarely carried through to the end in nature's laboratory. In meteorites we occasionally find this silicate in its final form.

In our work on the properties of silica we also found a way to make "quartz-glass," a material of such peculiar properties that it would no doubt be most useful in our everyday life. It differs from other glass but little in appearance, but can be heated to dazzling whiteness without melting, and then plunged into cold water with little danger of breaking. The high temperatures required, of course, make it difficult and expensive to prepare.

Another discovery which we made in connection with the same series of minerals (lime-silica) was very important and somewhat surprising. The peculiar and valuable properties of Portland cement have been commonly attributed to the presence of tricalcic silicate, but we found abundant proof that no such compound exists. It is not unlikely that the continuation of these investigations, which is now in progress, will reveal the true constitu-

tion of this cement, which is now prepared by routine methods, with rather inadequate knowledge of the chemical processes actually involved.

We have also found further and most interesting relations between the direction and linear force of crystal growth and the physical forces acting upon the growing unit at the time; we have developed some new methods for the optical study of our crystals; and our high temperature measurements have now reached quite extraordinary refinement. The aggregate error in our pyrometric apparatus is now no greater than 0.1° at 1,000° C.

The staff of investigators was increased on January 1, 1906, by the appointment of Dr. Fred Eugene Wright, formerly of the United States Geological Survey. Before his appointment it was necessary to have the microscopic study of our mineral products undertaken elsewhere. His cooperation has therefore made it possible for us to cover practically the entire ground over which we have worked within our own staff.

It has not been found necessary during the present year to add materially to the equipment described in the last annual report.

THE SCIENTIFIC WORK OF THE YEAR.

The crowded quarters which the laboratory has occupied in what is practically an office building have made it inadvisable to begin any of the systematic work at high pressures which has been contemplated from the beginning of the undertaking. Several pieces of special apparatus have been designed and built for this work, the mounting of which it has been found necessary to postpone until a special laboratory and more favorable conditions shall become available.

The published work of the laboratory during the year 1906 includes twelve papers, all of which have appeared (or will appear before the close of the year) in the scientific journals in the order and under the titles indicated below:

(1) The phase rule and igneous magmas. Arthur L. Day and E. S. Shepherd. Econ. Geol., 1, 286–288. January, 1906.

A brief criticism of certain sweeping and fundamental assumptions which had been made the subject of a geological discussion under this title by Mr. T. T. Read, in the previous number of Economic Geology.

(2) Der Isomorphismus und die thermische Eigenschaften der Feldspate. Arthur L. Day and E. T. Allen. Zeit. f. phys. Chem. 54, 1–54. January, 1906.

An extract from Publication No. 31 of the Carnegie Institution, printed in German.

(3) On wollastonite and pseudo-wollastonite—Polymorphic forms of calcium metasilicate. E. T. Allen, Walter P. White, and Fred Eugene Wright. Amer. Journ. Sci., (4), 21, 88–108. February, 1906.

Reviewed in last annual report.

(4) Quartz glass. Arthur L. Day and E. S. Shepherd. Science, n. s., 23, 670–672. April 27, 1906.

The peculiar properties of quartz glass, so called, which have made it a very important material for lenses, laboratory vessels, etc., made it seem that any investigation of quartz would be incomplete which did not include a careful study of the conditions of formation of this glass. From the investigation of silica (see No. 8, "Lima-silica series of minerals") we learned that if quartz is heated to 800° it becomes unstable, and will change its crystal form if given time enough to do so, going over into tridymite. This change is somewhat sluggish, and may be delayed far beyond that temperature. If the heating is then continued, the tridymite melts slowly, beginning at a temperature of about 1,600° C. The temperature is so high and the material itself so inert that the melting usually proves to be a totally different phenomenon from the melting of most other solids. It is still further peculiar in the fact that the liquid silica, after melting, is so viscous that it can hardly be made to run at all unless heated far above this temperature. With such a peculiar material, therefore, it is not surprising that great difficulty has been encountered in melting quartz down to a clear glass. Small single crystals have, to be sure, been melted in the oxyhydrogen flame to a clear liquid which cooled down without crystallization, but when the attempt is made to melt any considerable quantity of quartz it invariably comes out a spongy, white mass, which resembles common pumice stone, and is, of course, useless for any of the purposes to which glass is commonly applied. The viscosity is such that the air included between the solid fragments before melting is firmly held in small bubbles, which stoutly resist the usual methods of dislodging them.

It was found in the laboratory that quartz would not run together into a homogeneous mass after melting, without superheating, but the superheating of quartz in an electric furnace, with carbon electrodes, appears to cause a reduction of the silica and the formation of gas in sufficient quantities to cause more and larger bubbles. The problem which confronted us was, therefore, to get the quartz sufficiently fluid without its undergoing chemical change. We accomplished this by applying an air-pressure of about 500 pounds to the square inch, which proved sufficient to allow of considerable superheating without the usual decomposition. By this means clear quartz glass could be melted down from random fragments of pure material into clear, transparent blocks of a size suitable for many technical applications. It is probable that greater pressure would operate to still further hinder the appearance of gas and increase the certainty of a clear product, but the laboratory has no bomb strong enough to test this hypothesis.

The possibility of preparing this glass with reasonable facility in considerable quantities is extremely important, for when made it can not be melted before reaching a white heat, and its expansion coefficient, which is a fair measure of its tendency to break when heated, is insignificant.

(5) The determination of the feldspars by means of their refractive indices. Fred Eugene Wright. Amer. Journ. Sci. (4), 21, 361–363. May, 1906.

Of the many methods which have been suggested for the discrimination of the feldspars, perhaps none have received less actual attention from petrologists than those based on the refractive indices, and this, notwithstanding the fact that the refractive power of a mineral is one of its fundamental properties and can be approximately determined with comparative ease. The method described in this paper is based upon principles developed by Schroeder van der Kolk some years ago, but it has proved so effective in actual practice and so thoroughly serviceable in its present form that it has been thought to deserve separate publication.

(6) Errors in pyrometry. E. S. Shepherd. A paper before the American Electrochemical Society, May 3, 1906. Published in the Transactions of the Society.

The paper is a brief exposition of the errors common to the pyrometric apparatus now in use in the technical laboratories of the country.

(7) A modification of the Lasaulx method for observing interference figures under the microscope. Fred Eugene Wright. Amer. Jour. Sci. (4), 22, 19–20. July, 1906.

A description of a convenient device by which this well-known method can be applied without the usual disturbance of the microscope adjustment and consequent loss of time.

(8) The lime-silica series of minerals. Arthur L. Day and E. S. Shepherd. Read before the American Chemical Society at Ithaca, June 28, 1906. Extract in Jour. Amer. Chem. Soc., 28, 1089–1114. September, 1906. Full text, Amer. Jour. Sci. (4), 22, 265–302. October, 1906.

The feldspar investigation, published a year ago, was a study of a typical isomorphous mineral series without any breaking down of the components, limitations of solubility, or other complicating phenomena. In the interest of a systematic progression, it therefore seemed desirable to undertake an equally careful study of the eutectic relation. A further reason for undertaking this series lay in the fact that the most important single mineral contained in it had been made the subject of a special investigation during the previous year. The most important results of the investigation may be briefly stated as follows: In addition to lime and silica, the initial components of the series, only two compounds of these are capable of a stable, independent existence. These are wollastonite, which was found to exist in two different crystal forms, one of which (the common form) is stable below 1,200°; the other is stable only above that temperature. It was found possible to prepare both these forms in high chemical purity and to transform them from one to the other, thereby establishing all the conditions of their equilibrium. The melting-point of the higher form was found to be 1,512°. The second stable compound of these minerals is the orthosilicate of calcium, containing two molecules of lime to one of silica. Three different crystal forms of this min-

eral were found, and their optical and physical properties carefully established. One is stable from 1,410° to 2,080°, its melting-point; a second between 675° and 1,410°; while the third is only found at lower temperatures. It is interesting to note, however, that no one of these three forms exists in nature on account of the energy with which they are attacked by water and greater or less quantities of lime dissolved out.

The investigation of one of the components, silica, developed some further interesting information regarding natural formations, and incidentally led to a separate investigation, of which some account has already been given (No. 4 above). Silica was found to crystallize in two forms, quartz and tridymite, of which quartz is one of the commonest natural minerals. Tridymite occurs but rarely in nature. Under atmospheric pressure, however, silica can only crystallize as quartz below 800°. Above that temperature tridymite forms, and existing quartz becomes tridymite by slow inversion. Thus one of the most important and one of the commonest of the minerals found in nature must have formed at a relatively low temperature. The difference in density between these two forms of silica is relatively enormous—quartz, 2,654; tridymite, 2,318 (more than 13 per cent). The density of the glass is still lower—2.213.

(9) Schistosity by crystallization: A qualitative proof. Fred Eugene Wright. Amer. Journ. Sci. (4), 22, 224–230. September, 1906.

The schistose textures of many metamorphic rocks have been ascribed by Van Hise and others to the orienting influence of pressures, with a stress difference acting during the recrystallization of the rock in its new environment, solution taking place along the line of greatest strain and deposition along the line of least resistance and normal to the maximum stress. In such cases the rock cleavage is due to the parallel arrangement of its mineral components in planes perpendicular to the line of greatest stress.

Conditions of experiment in which crystallization under unequal stresses could take place were effected by using cubes of glass made by rapidly chilling various mineral melts, and by heating these slowly to the point at which crystallization began. The glass at that temperature is still so viscous as to be mechanically rigid and capable of supporting unequal pressures.

Textures similar to those of certain metamorphic rocks were produced in this way, and an experimental confirmation of the theoretical deductions thus obtained.

(10) Minerals of the composition $MgSiO_3$: A case of tetramorphism. E. T. Allen, Fred Eugene Wright, and J. K. Clement. To appear in Amer. Journ. Sci., November, 1906.

Magnesium metasilicate, when prepared pure, can be made to appear in four different crystal forms, of which two are pyroxenes and two are amphiboles. The only form which is stable at all temperatures is the monoclinic

pyroxene, melting at 1,521°. Into this form the other three modifications change more or less readily with the application of heat. If a melt of this composition be cooled rapidly, one of the amphiboles results; if somewhat less rapidly, an orthorhombic pyroxene identical with enstatite; if slowly, the stable pyroxene always reappears. Curiously enough, the stablest form of this composition has never been identified in natural rocks, although we are confident that intergrowths of it with enstatite must have been found and overlooked. It does sometimes appear in meteorites. On the other hand, the less stable pyroxene, enstatite, is a very familiar natural mineral.

The situation seems somewhat anomalous, and, indeed, no complete explanation for it has yet been found, but a curious side-light is thrown upon it by experiments which we made in the laboratory to the following effect: If magnesium metasilicate in any one of its crystal forms is mixed with a small quantity of a thinly fluid flux (calcium vanadate, magnesium vanadate, magnesium tellurite, magnesium chloride in the presence of dry hydrochloric acid) and heated, the stable pyroxene will always reappear. If, on the other hand, a solution be formed between the magnesium silicate and albite, orthoclase, or some other viscous silicate, enstatite, and even the orthorhombic amphibole crystallizes out quite readily. It thus appears that the retarding influence of viscosity is sometimes sufficient to prevent or postpone the crystallization of that form of the mineral which is relatively stablest in favor of some one of the unstable forms which may or may not go over into the stable form afterward. This final transition probably also depends upon temperature and viscosity.

The fourth form of this mineral is a monoclinic amphibole which we were able to form in aqueous solutions at low temperatures, but only occasionally and in small quantities from the melt. It appears to be unknown among natural rocks.

The final proof of the relation between these minerals was established by showing that each of the three lower forms passes into the monoclinic pyroxene with evolution of heat.

This paper, although restricted to a study of the different possible forms of a single mineral, was immensely instructive in explaining the appearance of relatively unstable components among natural rocks, and in showing that contiguous minerals, both in natural rocks and in pure mineral melts, are by no means necessarily in equilibrium.

In all branches of quantitative research, especially in its earlier stages, nearly as much attention requires to be paid to the methods of measurement as to the results. It therefore frequently happens that investigations which appear to bear only indirectly upon the ultimate purpose of the research are among the most important which the laboratory is called upon to undertake. During the past winter the methods of temperature measurement which we

have been using, and upon which the value of our results very largely depends, have therefore been made the subject of a searching examination. The results of this purely physical investigation are not only of value to us, but to all other investigators who have occasion to use high temperatures, to technical laboratories, and to a considerable number of the important industries. They will therefore be embodied in a series of separate papers, of which two are now ready for the press. These are concerned with the actual tools of our daily measurements, and will be briefly reviewed under their individual titles below. In addition to these, a fundamental investigation of the gas scale, in terms of which all high temperatures are now expressed, is well under way, and equipped with new and exceptionally perfect apparatus, but no report upon it can be made during the present year.

(11) Everyday problems of the moving coil galvanometer. Walter P. White. To appear in Phys. Rev. for November, 1906.

A discussion of the conditions of construction and of adjustment of moving-coil galvanometers in order to secure (1) high sensitiveness, (2) short period, (3) suitable damping, (4) constancy of zero, and of the possibility of obtaining some of these at the expense of others. The discussion has also been extended to include ballistic systems.

(12) The constancy of thermoelements. Walter P. White. To appear in Phys. Rev. for December, 1906.

The main source of error in thermoelectric measurement is due to inhomogeneity in the wires of the thermoelement. This may be original, and due to an imperfect distribution of the materials composing the wires, or may be acquired by exposure to contamination in their daily use. In the two classes of thermoelements in common use, platinum with platin-rhodium (Heræus) at high temperatures, and copper and constantan (an alloy of copper and nickel) at low temperatures, we find no original impurity which need affect temperature measurements by as much as 0.01 per cent (equal to 0.01° at 100° or 0.1° at 1,000° C.). The problem, therefore, resolves itself into an effort to discover what are the agencies which cause deterioration of the elements, the character of the error produced by their presence, and whether or not these substances can be excluded or rendered harmless.

In copper-constantan elements, inhomogeneities appear from two sources: (1) Variations in the hardness of the wire, due partly to unsatisfactory initial annealing and partly to bending the wires when in use. The effects of inadequate annealing are quite permanent at low temperatures, and are best avoided by rejecting wires in which they are found. Drawing the wire over the sharp corner of a board before using will usually produce uniform hardness, and no further trouble need then be feared from handling.

The second (2) cause of inhomogeneity arises from superficial oxidation of the wires. This can usually be prevented in various ways, or corrected by scouring.

The error, after these precautions have been observed, is less than 0.002° up to 40° C. These thermometers are, therefore, as sensitive as the finest mercury thermometers; they have a much greater range, and are more certain in their behavior. Still greater sensitiveness could be attained by using several elements in series, if sufficient galvanometer sensitiveness were available.

Platinum elements at high temperatures take up impurities which diffuse into the wire. Two sources of contamination are also found here: (1) The action of reducing agents (carbon, illuminating gas, etc.) upon the material of the furnace which sets free substances which combine with platinum (usually iron and silicon). Neither carbon itself nor the common gases containing it affect the elements. The second cause of contamination (2) appears in an oxidizing atmosphere, and has frequently been overlooked hitherto. It is due to the presence in the furnace with the element of vapors of the other platinum metals at temperatures above 900°. These (chiefly iridium and rhodium), when alone or alloyed with platinum, will penetrate both wires, and will cause low readings by diminishing the thermoelectric potential difference after a very short exposure. Glazed porcelain is a sufficient protection against these vapors, but not unglazed porcelain. When a wire is once contaminated with iridium or rhodium, there is no way to restore it except by cutting off the contaminated portion. The distribution of the contamination, as well as its amount, can be readily determined by a thermoelectric test against a piece of pure wire. A contaminated element can still be used for accurate work, provided it can be compared with a perfect element immediately afterward without changing the temperature gradient along the wire.

By observing the precautions above indicated, a platinum-platin-rhodium thermoelement was found to show no variations greater than one-twentieth of 1° at 1,000°—a remarkably high degree of perfection.

HISTORICAL RESEARCH.*

By J. Franklin Jameson, Director of the Department.

I beg leave to submit the following as my first annual report as director of the Department of Historical Research of the Carnegie Institution of Washington. I arrange it under the three heads of "General plans," "Work of the past year," and "Special plans for 1907." Since my tenure of this office began on October 1, 1905, I aim to cover in the second section of the report the transactions of thirteen rather than twelve months.

GENERAL PLANS.

The proper functions of a department of historical research in the Carnegie Institution of Washington are defined by the nature of the processes of historical work on the one hand, and on the other hand by the present status of such work in the United States and the form of its organization.

The normal processes of historical work would commonly be said to be four: The finding of the original materials, printed or unprinted; the putting of them into accessible and well-edited print, if they have not already that form; next, the production of monographs; and, finally, the composition of general histories. Unless under circumstances quite exceptional, the last two processes are better left to the free action of individual scholars. Given the materials, they will produce monographs and histories in the future, as they have in the past, and of a better flavor than those which might be turned out by an organized institution. In the main, it must be the proper function of an organized and permanent institution, disposing of ampler resources than most individual historians can command, to carry on the primary, fundamental, and costly tasks of finding the materials or guiding men to them, and of printing such of them as are unprinted and most deserve print, selecting those which are likely to give the greatest possible aid and incitement to the production of good monographs in important fields. For us at any rate, *melius est petere fontes quam sectari rivulos.*

Accordingly, the publications of such a department will naturally fall into two classes: A series of reports, aids, and guides, mediating between the worker and his materials, printed or unprinted, and a series of texts; and the main business of this department must be to plan, and so far as possible to execute, those publications, of these two sorts, which are most needed, or most likely to be of large utility, in the present state of American historical work.

* Report for the year ending October 31, 1906. Grant No. 313. $17,600 for investigations and maintenance. (For previous reports see Year Book No. 3, pp. 65–79, and Year Book No. 4, pp. 232–237.)

REPORTS, AIDS, AND GUIDES.

If no such helps had hitherto been constructed and we had carte blanche, our natural course might be to attempt the preparation, on a systematic plan and a grandiose scale, of a comprehensive and minute survey of all the original materials, printed and unprinted, for the history of the United States. (The materials for the history of other countries, we may assume, will be better cared for by them.) But we have not carte blanche. Many finding-lists, many archive-reports, already exist in print. Governments and historical societies have furnished guidance to certain sorts of historical material, and stand ready to furnish still more. The department should, on the negative side, avoid duplication and competition; on the positive side, it should seek and promote cooperation. It may very well cherish the ambition to supply what is still lacking of the grandiose scheme, to accomplish by its own means and efforts the great general survey, minus such parts of it as have already been achieved or are likely soon to be achieved by others. But a task so defined is, from the nature of the case, composed of distinct portions, which may be planned separately and taken up in the order of their importance. The ideal outlines of a perfect general survey may be kept always in mind; we need never lose from sight the relations borne to it by the particular fragment with which we are at the time engaged, but we are released from the necessity of pursuing an inconveniently logical order, and can undertake our partial guides as they are most pressingly needed or as they are most conveniently approached.

To speak first of unprinted materials, it is plain that there are three stages in the process of mediation between them and the historical scholars who may wish to use them: First, the preparation of general descriptions of them, as they lie in masses in their respective repositories; secondly, the preparation of calendars or itemized lists of them, usually in a chronological order; thirdly, the editing and putting into print of those which are most important. While the superior value of some materials may properly bring them into the stage of calendaring or printing long before all the general descriptions of the first-named order have been completed, it remains in general true that in the earlier years of our work the compilation of general descriptions of archive-material is logically entitled to the leading place.

Among reports or guides of this sort, the most obvious desideratum was that of a guide to the archives of the Government at Washington; and such a volume was prepared and issued under my predecessor, Professor McLaughlin. In this great field of the national archives, which our local circumstances press upon our attention with peculiar force, the calendar stage may for certain classes of material be appropriately reached soon. Of the archives of the States, a dozen have been reported upon with a fair degree of completeness by the Public Archives Commission of the American Historical

Association, and a dozen other States have special commissions of their own engaged in the preparation of similar reports. Most of our older large cities have, in some degree, made similar provision. So far as the main records in the central archives of the States are concerned, what is most important is in a fair way to be executed, either by such agencies or by the historical societies, which in this country are exceptionally rich and influential. Yet all the older of these archives contain great quantities of historical material which are no part of their regular series of legal records, which relate rather to the history of other States or of the Union than to that in which they are found, or which lack significance till combined with materials found elsewhere. In work upon documents of this class the department has a large field, and another, of indefinite magnitude, in dealing with those which still remain in private possession.

Moreover, to exploit the unprinted materials for American history which are to be found in archives outside the United States is not only an appropriate task for such an organization as this department, but one of the most imperative and immediate. In the first place, the American colonies having been under the control of various European governments during all their formative period, there are many cases in which America contains only secondary or derivative records of transactions, of which the primary or fundamental documents are in Europe. Lacking these, we shall often miss the central threads of colonial administration. Secondly, since not simply the colonial governors and governments, but also the emigrants themselves, came from Europe, it is as true of the history of American social institutions as it is of American constitutional and political history, that it is vain to attempt to write it without the aid of materials to be found in Europe rather than in America. Thirdly, even for the period since the attainment of American independence, there is a large branch of our history which can never be adequately treated by means of American materials alone, namely, our diplomatic history. To attempt to base this on purely American materials, without taking into account the documents which exhibit the European side of the same transactions, would be neither reasonable nor scientific. It would amount to shutting out half the light. Finally, if needful, a quantitative and pragmatical argument might be adduced. It is probable that, for the portion of American history prior to 1815, there is a greater amount of original document in Europe than in America. Moreover, of that which is in America, it is certain that a larger portion has been printed than of the corresponding masses of American material in Europe, for in the eyes of European governments and other printing agencies such material has naturally borne a wholly secondary importance in comparison with materials bearing directly on their own history, while to American governments it has seemed fundamental.

Here also, as in the case of American archives, the first step is properly that of preparing summary descriptions or general inventories of the Amer-

ican materials in the respective archives. There have been many partial skimmings or deflorations of them by American searchers or agents of States. But the partial or casual quality of their data makes it impossible to bring them by supplementary efforts up to the full measure of what we want, and great stores of material are now thrown open that in former days were excluded. We must first find out what there is, by thorough and orderly search, proceeding through every division of the archive, not with a view to the production of one book or to the illustration of the history of one State, but with an eye to the interests of all present and future workers in American history, in whatever topic, region, or State they may be interested. Acting upon this plan of procedure, my predecessor instituted three elaborate projects of research. Prof. C. M. Andrews, of Bryn Mawr, undertook the preparation of a guide to the materials for American history prior to 1783 to be found in the archives of Great Britain. Prof. W. R. Shepherd, of Columbia University, undertook a similar guide, but not limited chronologically, to the three principal archives of Spain. Mr. L. M. Pérez was sent to examine the archives of Cuba. It was natural that England and Spain should be first undertaken. In course of time we ought to complete the work there, by bringing our English inventory down from 1783, by embracing the minor national repositories in Spain, and in both countries by furnishing similar guidance to the materials for American history in provincial and local, in ecclesiastical, nobiliary, and other private archives in England, Scotland, Ireland, and Spain. But a more pressing need is for guides to the documents for United States history in the main archives of France and Mexico. These two countries have the first claim upon our attention, France because of the high importance of her relation to the history of the Mississippi Valley and to that of American diplomacy; Mexico, because (with the possible exception of the Vatican archives) no archive of similar importance to our history has been so little explored. Of the archives of the Dominion of Canada, on the other hand, that great storehouse of historical material, one of the most ample in the western hemisphere, we may say with some confidence that no large archive has ever so fully made known in print its contents. An inventory of what it contains for the history of the States may therefore without harm be deferred, especially as it is at the beginning of a new administration, with large ideas of development which, we may hope, will be so well sustained as soon to make obsolete any handbook that we might prepare. Meanwhile, through the cordial relations which subsist between the archivist of the Dominion and this office, we may hope shortly to possess all needed information as to what the lesser archives of Canada possess that has value for our historians.

After France and Mexico should come the archives of Rome. The extent of the Roman archives, their state of preservation, and the ecclesiastical relations which subsisted between the Roman curia and especially the French

and Spanish portions of our territory, bring it about that here we have a great and most interesting body of material for our history, and by reason of the late date at which the Vatican archives were thrown open little systematic work in the American field has yet been done within their walls. The attempt on our part to explore the Roman collections thoroughly can not be at once begun. The problem is so important and so complex as to demand for itself a special report. But it has a high place in our list of agenda.

Next in importance come the archives of Germany, including the German parts of Austria and Switzerland. Here we have to deal not only with the central archives, rich in documents for diplomatic and other public history, but, because of the peculiar importance of German emigration to America, with many local, university, and private archives and libraries, abounding in the materials which illustrate that remarkable and momentous movement. At later periods we may look forward to dealing with the archives of the Netherlands, Portugal, Russia, and Scandinavia, and with those of Central and South America. It may be mentioned that, apart from an order of countries dictated by American considerations, our general course of procedure with respect to foreign archives is closely similar to that pursued by the most sagacious of the European historical agencies.

There is, however, one peculiar aspect of our plans of procedure that should be briefly commented upon. Of the American States, there are at least twenty-six whose territory was once, in whole or in part, in greater or less degree of completeness, under the civil control of France and the ecclesiastical governance of Rome; some twenty-two under the rule of Spain. In many of these, especially in the Mississippi Valley, there are active historical societies or State departments of history, of which several are upon the point of undertaking extensive projects of transcription and publication of material from European archives illustrating their respective histories. But it is apparent that all this enthusiastic effort might lead to much wasteful duplication if cooperation were not carefully provided for. While the spirit of cooperation exists in abundant measure in these institutions, it is not too much to say that its course can be made much more effective and complete through the work of this department. The clearing-house, we may say, was instituted just in time. For example, our proposed guides to the American material in the Spanish, French, and Roman archives will be, it may fairly be said, invaluable to these organizations at the present juncture, relieving them of much preliminary labor which one agency can do for all, and promoting cooperation by laying before them a detailed and scientific map of the territory in which they are to find their respective fields of work. In many other ways it is possible for this department, while perfectly avoiding "entangling alliances," to further mutual understanding and mutual help among these organizations. In view of their ardor and of the increasing resources which they are plainly destined to command, I do not know

whether there is any field of our activities where each hundred dollars of expenditure brings so large a future profit to the cause of historical science in the United States.

Hitherto this report, in treating of the ideals of a department of historical research, and of the preparation of reports, aids, and guides as a necessary element in its program, has spoken only of guides to unprinted materials. I should be sorry to be supposed to hold that such a department has no function with respect to those that are in print. The distinction between the two is broad as respects convenience of use, and therefore has its proper claim to be regarded in our work. But for many purposes in historical science the distinction simply does not exist. The worker wishes to have before him all the first-hand statements that bear upon his theme. It is little to him, save as to expense perhaps, that some come to him in the guise of print, some in that of manuscript. Multitudes of them are annually passing over from the latter to the former class. The distinction is external and superficial. An organization that means to do what is most useful in the way of mediating between workers and their original materials will not adopt it as a primary basis of classification. Such an organization will not print in its text-series that which is already printed, but in constructing some of its aids or guides, as, for instance, in supplying historical scholars with lists of materials of specific sorts, such as lists of colonial charters, or governors' commissions, or legislative journals, or missionary relations (a most useful variety of guide, of which we should have many more, of the type of certain European regesta), it will surely list without distinction those members of a series that are printed and those that are not. Whatever may be thought of ordinary bibliographies—lists of writings original and secondary, good, bad, and indifferent, on a given subject—for classified lists of original materials there will always be a legitimate demand.

It is not without reason and intention that a heading making reference to aids as well as to reports and guides has been chosen for the title of the present section of this report. Besides reports upon archives, and guides to particular masses of archival and other material, there are certain sorts of historical reference-books that can best be produced by endowed institutions, as the Art de Vérifier les Dates was produced by the Congregation of St. Maur, as the Allgemeine Deutsche Biographie has been produced in our time by the Bavarian Historical Commission, or as the great historical atlas of the Netherlands is being produced by the Historical Society of Utrecht. Several such enterprises may ultimately, with permission, be proposed by the department, the most interesting and important among them being the project of an atlas of American historical geography comparable with the best of the historical atlases now in course of preparation in and for various European countries.

Textual Publication of Documents.

As has been intimated in a previous paragraph, the work of the department in its earlier years may well consist mainly of the locating of materials and the publication of information respecting them. But it is not needful that the second natural division of its publications, the series of texts, should be wholly postponed till the first has been completed. On the contrary, several collections of documentary texts urgently demand publication, and can be prepared concurrently with our series of guides. For a survey of the general subject of desiderata of this class, I may refer to an article entitled "Gaps in the published records of United States History," which I printed in the American Historical Review for July, 1905. The part which this Department may play in supplying these deficiencies must always be defined in consideration of, and sometimes in consultation with, other agencies, such as historical societies and governmental bodies. Thus while such series as pertain to individual States should be left to be cared for by the States themselves, there are many series which, while they belong to many States, are no natural concern of the national government, series of which the materials are to be obtained from Europe, or lie so scattered in the archives of many States that until they are brought together their significance and serial quality are not appreciated. Examples of the former class would be the acts of the Privy Council of Great Britain, proclamations of the English or orders of the French and Spanish kings relating to these colonies, the journals of the Board of Trade and Plantations, or the American debates of the House of Commons. Another example, and one which has been claiming the attention of the department during the past year, is a collection of all those treaties and parts of treaties between European powers which have a bearing on the history of the United States. A typical instance of the second class mentioned, collections whose materials must be assembled from many States, but which none the less have a high degree of unity and value when assembled, is that of the letters which delegates to the Continental Congress and the Congress of the Confederation wrote to their respective States describing its proceedings, a collection which was undertaken by my predecessor, and the value of which was emphasized in his last report. Again, the State Trials of the United States deserve to be collected. The papers of many eminent statesmen call for collective editions, or better editions than have appeared, *e. g.*, the correspondence of John Adams, of Richard Henry Lee, of James A. Bayard, of John Quincy Adams, of James H. Hammond, of Jefferson Davis, or of Alexander H. Stephens, not to mention those whose papers are in the Library of Congress or are otherwise likely to be cared for by existing agencies.

Miscellaneous Duties.

In its capacity of clearing-house for the historical profession, the Department must endeavor to accumulate and keep on file in a convenient manner all possible information respecting manuscript materials for American history, especially those which are scattered or difficult of access, and to do what it can to facilitate use of these by scholars. It must also mediate between historical scholars, the country over, and the archives of Washington, by making searches of limited extent for them, indicating available materials, answering questions, and making arrangements with copyists. It should aid with particular zeal the efforts of societies and State departments of archives and history. The editing of the American Historical Review, the organ of the profession, is, inevitably, closely associated with its work.

WORK OF THE PAST YEAR.

I can not easily express my deep sense of obligation to my predecessor, Professor McLaughlin, for the condition of advancement and of order in which he turned over to me, on October 1, 1905, the affairs of the department. I am sure that all who work in the department and all to whom its work is of service will continue to be grateful to him for the admirable intelligence and skill with which he organized and for two years carried on that work.

Reports, Aids, and Guides.

Messrs. Van Tyne and Leland's Guide to the Archives of the Government of the United States in Washington having come to be practically out of print, a second edition is in preparation, and should be in press by January. While the form of the Guide will not be changed, such corrections will be introduced as have been made necessary by the receipt of additional information or by occasional shiftings of archive-material from one place of deposit to another. In many places the text will be considerably amplified. A very full report has been prepared on the important body of material in the Bureau of Indexes and Archives of the Department of State, the records of territories in that Department and elsewhere have received particular attention, and the account of the records of the Post Office Department has been very much amplified. While this revised edition can in no way be made a definitive one, it will be considerably larger and more informing than that of 1904.

Mr. McLaughlin's Report on the Diplomatic Archives of the Department of State, 1789-1840, also out of print, has been reissued with only a few slight alterations.

To meet and to stimulate increased interest in the religious history of America, an interest felt not only by workers in church history but by the

most intelligent students of the history of American civilization, it was resolved that an attempt should be made to furnish a methodical guide or inventory to the large but scattered mass of unprinted historical material preserved in the archives of the various religious bodies and missionary societies, and in the libraries of theological seminaries and denominational colleges. The Protestant portion was first taken up. Prof. William H. Allison, of Franklin College, was chosen as the fittest person to conduct such an inquiry. In explanation and furtherance of its objects a printed circular was extensively employed.

Most of the work was done in the summer. It met with cordial cooperation and much success, with some drawbacks, due to the summer closing of libraries or the absence of custodians. The agent visited six denominational archives in New York, six in Philadelphia, four in Boston, three in Louisville, two each in Cincinnati, Princeton, Rochester, and Allegheny, and one each in Cleveland, Oberlin, Dayton, Xenia, Springfield, and Urbana, Ohio; Gettysburg, Lancaster, Swarthmore, and Upland, Pennsylvania; Wilmington, Delaware; New Brunswick, New Jersey; Hamilton, Canton, and Syracuse, New York, and Hanover, New Hampshire. A highly satisfactory report of progress has been rendered. By the end of another summer Mr. Allison hopes to complete the visitation of such archives as are to be covered by the final report.

Prof. Charles M. Andrews, of Bryn Mawr College, had been early engaged by the department to prepare in England a guide to the materials for American history prior to 1783 to be found in London archives. The results of his labors down to October, 1905, are described in Mr. McLaughlin's report of a year ago. At that time he returned to America with an extraordinarily complete mass of notes upon the American papers in the Public Record Office, the British Museum, and the Bodleian Library. From these he has been preparing the desired book as rapidly as his college duties have permitted. It seems probable that by January it will be finished and ready for the printer.

Meanwhile it seemed desirable, both to Professor Andrews and to the director, that the manual should not be confined to the three repositories which alone the former had been able to examine thoroughly, but that such supplementary searches and notes should be made as would complete it for the whole circle of public or semi-public archives in London. To this end, as Professor Andrews could not go to England again, Miss Frances G. Davenport of this department went to England in June, after such conference with him as would enable her to collect materials on a plan uniform with his. The repositories which she was instructed to examine for their American materials were the archives of the House of Lords (never hitherto examined with care for purposes of American history, it is believed), of Lambeth Palace, of Fulham Palace, of the Society for the Propagation of the Gospel, of the Hud-

son's Bay Company, of the General Post Office, of the Catholic province of Westminster, and of the Royal Society, Sion College, and Dr. Williams's Library. By the kindness of Sir Henry Graham, Clerk of Parliaments, the Archbishop of Canterbury, the Bishop of London, the Archbishop of Westminster, Lord Strathcona, governor of the Hudson's Bay Company, the Secretary to the Post Office (through the good offices of the American ambassador), and other authorities in charge of these collections, ample facilities for Miss Davenport's work have been afforded. It is expected that it will be completed within two months after the date of this report. The results will then be combined with those obtained by Professor Andrews, and the Guide produced.

The guide to the materials for United States history in the three chief Spanish archives is not so near completion. Professor Shepherd's duties at Columbia University and his voyage to Rio Janeiro have delayed it, but it will apparently be finished by the end of the calendar year. Mr. Pérez's report on the Cuban archives is finished, and ready for the press. By the kindness of Dr. Arthur Doughty, C. M. G., archivist of the Dominion of Canada, arrangements have been made whereby two agents of his office who are engaged in searches of the archives of the Maritime Provinces and of the ecclesiastical province of Quebec, respectively, Dr. James Hannay and Father P. M. O'Leary, will communicate to this department reports upon all material for the history of the United States that they may discover.

It was from the first intended that all the reports of the department upon foreign archives should be accompanied with lists of the transcripts of documents in foreign archives which exist in American public collections, in order that the historical inquirer might run no risk of expending time and money in seeking in Europe documents of which copies were accessible nearer home. Mr. McLaughlin's last report explained what had been done toward this end by Mr. W. G. Leland, of this department, in Virginia,* North Carolina, and South Carolina. During the past year he has advanced this task much nearer to completion, especially as regards the English and Spanish material, which will be the parts first needed. The list of unprinted transcripts from the British archives has been continued to include the documents in the Massachusetts archives and in the libraries of Harvard University, the Massachusetts Historical Society, and the Maryland Historical Society, in all about 5,000, additional to about 10,000 that had been calendared a year ago. The list of unprinted transcripts from the Spanish archives at present includes the documents in the possession of the Louisiana Historical Society and the Missouri Historical Society, in the library of Col. R. T. Durrett, of Louisville, and in that of Harvard University, in all about a thousand. The transcripts in the New York Public Library are next to be undertaken by

* Our list of transcripts in the Virginia State Library has been printed by the librarian in a recent report.

Mr. Leland, and arrangements have been made to catalogue those in the State Historical Library at Madison, Wisconsin. The whole list, so far as England and Spain are concerned, is expected to be brought to completion by the spring of 1907.

For similar reasons, indeed for obviously stronger reasons, lists of printed documents obtained from foreign archives were planned from the beginning of this work. The English list, which had been compiled some years ago by Miss Gertrude Kimball, of Providence, under the auspices of the American Antiquarian Society, and which was turned over to this Department, has been brought down to date and otherwise completed by Miss Kimball, and contains about 15,000 items. A similar list relating to the Spanish archives has been compiled by Miss Mary Griffin, and contains about 2,000 items.

Under the rubric of "aids" mention might be made of a code of "Suggestions for the printing of documents relating to American history," which was jointly prepared by Prof. Edward G. Bourne, of Yale University, at that time chairman of the Historical Manuscripts Commission of the American Historical Association; Mr. Worthington C. Ford, Chief of the Division of manuscripts in the Library of Congress, and the director of this department. It was printed by the American Historical Association, and has been given extensive circulation among historical societies and students.

Texts.

Miss Davenport has been engaged throughout the year with the preparation of a volume which shall contain accurate texts of those treaties or parts of treaties between European powers which have a bearing on the history of the United States. In spite of their obvious importance to American history, these texts are difficult to procure. Many have never been printed accurately; some have never been printed at all. The contemplated volume will give texts carefully collated with the originals in European archives, and historical introductions and notes by Miss Davenport.

The second of our text publications on which progress was made during the year was that embracing the letters of delegates to the Old Congress, described more fully in a preceding paragraph and in Mr. McLaughlin's last report. The endeavor to locate additional collections of such letters has been continued by Mr. Leland through correspondence and personal visits. In Rhode Island a systematic search is being made by Miss Kimball. A beginning has been made in the archives of Massachusetts. The collections of the Connecticut Historical Society have been thoroughly searched and all the letters of this sort found there, some 200 in all, have been copied. In New Hampshire, through the kind offices of Prof. Herbert D. Foster, of Dartmouth College, a collection of 58 letters has been located and copied.

As nearly 250 letters had previously been copied in Virginia and North Carolina, there are now on hand about 500 letters. Further extensive copying will be postponed until experiments now in progress, founded on suggestions made at the Congress on Facsimiles at Liège, have demonstrated whether or not the copying can be done as economically and rapidly by some photographic process. If so, the advantage will be great in the matter of proof-reading, since the scattered situation of the originals will make collation of proof-sheets with them a difficult matter.

Miscellaneous Operations.

So far as possible, all important inquiries addressed to the department by serious students have been answered, especially such as related to historical materials in Washington. The correspondence increases so rapidly that it amounts to three or four times what it was two years ago.

Under the supervision of the department, but at the expense of the Michigan Pioneer and Historical Society, large portions of the papers of Henry R. Schoolcraft, at the Library of Congress and the Smithsonian Institution, have been copied for the society. In a similar manner, a large number of documents relating to the Illinois country during the period from the expedition of Gen. George Rogers Clark to the organization of the Northwest Territory have been copied for the Illinois State Historical Library, and a lesser number, relating to the period of Spanish rule in Missouri, and derived from the archives of the United States and of Cuba, for the Missouri Historical Society. The effort is constantly made to exhibit toward historical societies and State historical departments, as well as toward individual students, a helpful spirit. It is possible that success in mutual cooperation of this sort may be furthered by the return of the director to the position of chairman of the Historical Manuscripts Commission of the American Historical Association, which he occupied for some years at its inception. It is certain that it has been signally furthered by the personal visits which Mr. Leland has paid during the past year, in the course of the searches mentioned in a preceding paragraph, to historical societies and public archives in Richmond, Raleigh, Columbia, Charleston, Savannah, Atlanta, Montgomery, Mobile, New Orleans, Nashville, Louisville, Frankfort, and Charleston, West Virginia. Many favors and courtesies have been received from such organizations by various members of the staff. As instances of possible usefulness on our part may be mentioned aid rendered the archivist of West Virginia in locating certain bodies of material, and the discovery at the Department of State of a large body of North Carolina archive-matter which has since been restored to the State.

An instance of cooperation upon a wider field is the appointment of Mr. Leland, with the consent of the director, to supply each year the American

portion of the Jahresberichte der Geschichtswissenschaft, published by the Historical Society of Berlin.

In accordance with the practice established during Mr. McLaughlin's tenure of this office, several persons competent in historical investigation have been aided to come to Washington for that purpose by grants from the appropriation made toward that end. They were: Mr. J. S. Fox, assistant in the University of Michigan, studying certain aspects of the organization of colonial legislatures; Mr. J. P. Bretz, assistant in the University of Chicago, studying the extension of the United States postal system into the West; Mr. J. K. Lacock, studying the history of the Whisky Insurrection; Mr. C. S. Larzelere, studying the internal boundaries of the United States; Mr. J. L. Conger, of the University of Wisconsin, making researches into the history of nullification in South Carolina; Prof. E. C. Barker, of the University of Texas, who came to examine papers relating to Texas history preserved in the Washington archives, and Dean W. H. Isely, of Fairmount College, making similar inquiries into the history of the strife in Kansas in 1854-1859. Our practice has been to require that each such grantee shall at his departure deposit in our office, for our benefit and that of future inquirers, a more detailed account than has hitherto existed of the contents of that portion of the Government archives which he has especially examined. I believe that, under these arrangements, such grants are useful, and I hope that they may be continued.

While the Library of Congress must always be our main reliance for books, and while we are given the most liberal opportunities there, yet since we are at twenty minutes' distance the department can not do its work properly without having immediately at hand a certain supply of books, chiefly books of reference and books respecting archives. With the permission of the President, parts of the unexpended portions of the appropriations of 1905 were used in gathering together a small working library of this sort.

By permission of the Trustees, the director spent the spring in Europe, sailing from New York for Naples on March 24, and returning to Boston, from Liverpool, on July 10. The trip had two objects. The first was to inspect several of those establishments or organizations in western Europe whose work most closely resembles that which this department hopes to do, to examine their material equipment and converse with those in charge, in order to derive out of their experience suggestions for the future conduct of our operations. Great kindness, interest, and willingness to assist were everywhere manifested. It would be difficult to summarize observations of quarters, equipment, methods, and plans, extending over a period of three months. I am confident, however, that much has been gained, especially in the way of enlargement of views and the making of profitable acquaintance, that will have definite outcome in the work of succeeding years.

At Rome the several historical institutes were inspected which the various nations have established since the opening of the Vatican Archives by the late Pope, and which bear some such relation to those archives as that which this department aims to sustain toward the archives in Washington. At the École Française, the Prussian, Austrian, and Dutch institutes, and that of the Görres Gesellschaft, respectively, much valuable information was obtained from Mgr. L. Duchesne, Prof. Paul Kehr and Dr. Arnold O. Meyer, Dr. Heinrich Pogatscher, Abbé Gijsbert Brom, and Mgr. Stephan Ehses. At Quaracchi the historical establishment of the Franciscans, the College of St. Bonaventure, was visited. At Munich there was profitable conversation with Prof. K. Th. von Heigel, secretary of the historical commission connected with the Bavarian Academy; at Leiden and the Hague with Prof. P. J. Blok, Dr. T. F. van Riemsdijk, archivist of the Kingdom, and Dr. H. T. Colenbrander, members of the Commission of Advice on National Historical Publications; at Ghent and Louvain with Dr. F. Vanderhaeghen, librarian of the University of Ghent, and with Profs. Paul Fredericq and Henri Pirenne and Abbé A. Cauchie, members of the Royal Historical Commission; at Paris, London, and Oxford with various gentlemen connected with similar commissions or with the national archives, especial kindness being received from Prof. Ch.-V. Langlois, of the University of Paris, and Mr. Hubert Hall, of the Public Record Office. No one of these various institutions occupies a place precisely similar to that of this Department, but each has functions so largely similar, on one side or another, that inquiry and comparison could not fail to be highly interesting and instructive.

A second object of the mission was to do what could be done, by inquiries and tentative and unofficial approaches, to pave the way for those future archive-searches the necessity for which has been exposed in a previous paragraph. This object received especial attention at Rome, the interest and complexity of the task to be pursued there being, as already explained, exceptionally great. Besides the suggestions received from some of the scholars named above, I could not fail to mention with gratitude the aid and information graciously imparted by Cardinal Merry del Val, Secretary of State; Cardinal Gotti, prefect of the Congregation of the Propaganda; Father Ehrle, prefect of the Vatican Library; Mgr. Wenzel, subarchivist of the Vatican archives; Father Leonard Neukirchen, definitor-general of the Franciscans; Prof. Umberto Benigni, of the Propaganda; Father Thomas Hughes, S. J.; Abbé Pierre Richard, Mr. W. H. Bliss, English record agent, and Father Leonard Lemmens, of Quaracchi. I feel confident that, when the proper time arrives, unusual facilities will be afforded for whatever researches we may undertake. Preparations toward future archive-searches elsewhere in Italy, and at the Hague, Paris, and London, were a simpler and easier matter.

SPECIAL PLANS FOR 1907.

Reports, Aids, and Guides.

Besides the maintenance of those varieties of work which have now become established routine to the department, the year 1907 ought, without much doubt, in view of the preparations described above, to see the issue of four publications: The amplified edition of the Guide to the Archives at Washington, and the guides to the materials for American history in the archives of Cuba, Great Britain (to 1783), and Spain. The last-named volume can without difficulty contain our notes of manuscript transcripts and printed documents. The transcripts and printed documents from English archives are so numerous as to require that our notes on them be published separately from the Guide, in 1907, if possible; if not, in 1908.

The work most needed in respect to the Washington archives is the preparation of an itemized calendar of the papers relating to the Territories, beginning with the Northwest Territory. It is for this class of papers that, owing to the increasing activity of historical work in the West, there is the largest demand for fuller information than is given in Messrs. Van Tyne and Leland's Guide. Moreover, they are so scattered through various Departments and bureaus, and have so little relation to the present business of the Federal Government (nearly all these Territories having now become States), that no single agency of that Government will be likely to feel an especial interest in the collection of information regarding them from all the depositories in Washington, while the cordial aid we have received in the preparation of the new edition of the Guide makes us confident that we shall receive every needed facility in this proposed advance into the second stage of exploitation of archives. During the year it may be expected that Professor Allison's inventory of historical materials in Protestant religious archives should be made nearly or quite ready for publication.

As to the archives outside the United States, I desire to undertake first, and in the year 1907, the exploration of the archives of France and Mexico, on a plan similar to that which has been pursued in the case of England. The reasons in both cases have been set forth in an earlier paragraph.

Texts.

The collection of European treaties and of letters of delegates to the Old Congress may be expected to make large progress during the next year, the former possibly reaching completion. We ought also to make a beginning with some one of those series from British sources of which I described the need in the article in the American Historical Review, to which reference has already been made. In view of movements on foot by other organizations, it now appears that the one for us to undertake, one certain not to be

undertaken elsewhere, yet of great importance, is the collection of all accessible reports of debates in Parliament respecting American affairs previous to 1783. Doubtless it is popularly supposed that all this is in Cobbett; but this is far from being the case. Without going into the complicated bibliography of the pre-Hansardian debates, it may be said, briefly, that large parts of the debates can only be found by searching a variety of antiquated collections, wrongly supposed to have been superseded by Cobbett, and few of which are to be found in the libraries of the United States; while large amounts of additional material exist only in manuscript, some in England, others, only recently discovered, in France. It would be a great boon to students of the British administration of our colonies, and to students of our colonial history in general, if from all sources, printed and manuscript, a scholarly edition of the American portion of these debates were to be compiled, and it is hoped that a beginning may be made at once.

HISTORY.

Ferguson, W. S., University of California, Berkeley, California. Grant No. 338. *A History of Athens from Demosthenes to Plutarch.* $1,200.

Under this grant a preliminary study has been completed, the results of which are published in vol. 1, part 5, of the University of California Publications in Classical Philology and summarized in the Berlin Philologische Wochenschrift for August 4, 1906. During the past summer Professor Ferguson has been busy in the library of Harvard University, and reports substantial progress with the work itself. Since the task calls for travel and investigation in Europe during the coming twelve months a final report can not be presented in this Year Book.

Haskins, Charles H., Harvard University, Cambridge, Massachusetts. Grant No. 328. *Study of the documentary materials for Anglo-Norman history.* (For previous report see Year Book No. 4, p. 238.) $1,000.

Besides such work as he was able to accomplish in the course of the year in the printed sources, Professor Haskins spent two months of the summer vacation in examining systematically the material for the Anglo-Norman period preserved in local archives and libraries throughout Normandy, and at the Bibliothèque Nationale, the British Museum, and the Public Record Office. A fair amount of valuable material was secured, and it is hoped that the exploration of the documents to be found in Normandy and at Paris may be completed next summer. Attention has been directed particularly to the sources for the history of the military system and of judicial organization and procedure. At the present stage of the investigation not much can be attempted in the way of reaching definite conclusions, but three brief papers are in preparation and will appear in the course of the coming year.

Wright, James M., Johns Hopkins University, Baltimore, Maryland. Grant No. 269. *Study of the history of the Bahama Islands since 1848 and a complete report of the contents of its public archives.* (For a previous report see Year Book No. 4, p. 239.) $250.

Abstract of Report.—Dr. Wright's report of last year concerned the archives of the Bahamas, and he now reports that he has in hand 200 pages of manuscript of this material. During the year complete reports concerning the wrecking industry of the Bahamas, the ceremonial use of public burial grounds, and educational matters have been worked up. Work has also been begun on descriptions of a cholera epidemic at Nassau, of a financial stringency, and how the colony passed through it, and of the state of the out-islands, their public works, etc. Other topics have also been touched upon, but the materials for reports are incomplete as yet.

LITERATURE.

Sommer, H. Oskar, "Astolat," Camberley, Surrey, England. Grant No. 347. *Preparation of results of researches on Arthurian romances.* $2,000.

Abstract of Report.—The manuscript of the first two parts of this work, the history of Joseph of Arimathea or the Holy Grail and the Merlin or the early history of King Arthur, have already been received from Dr. Sommer, and preparations are being made for appropriate publication.

The Merlin, which Dr. Sommer formerly transcribed and printed privately, has been improved upon as far as possible by the addition of reference numbers to the English prose version edited by H. B. Wheatley and the metrical version edited by Dr. E. A. Kock (E. E. T. S.).

Dr. Sommer has two contributions to the criticism of the Arthurian cycle, one dealing with the Tristan manuscripts, the Queste of the Grail, contained therein, and a fragment of a lost Suite de Lancelot. This has been sent to Professor Kittredge, of Harvard, for publication in Modern Philology. The other contribution is a criticism of the remarks of Dr. Douglas Bruce on the English version of Mort Arthur in the Harl. manuscript 2252. This is in the hands of Professor Bright, of Johns Hopkins University, for publication in one of the American journals of philology.

MATHEMATICS.

Lehmer, D. N., Berkeley, California. Grant No. 374. *Comparison of factor table of first ten million numbers with manuscript tables of Kulik.* (For a previous report see Year Book No. 3, p. 121.) $400.

A preliminary count has been made of the primes in the tenth million from Kulik's manuscript. This manuscript has, however, not yet been checked against any other tables and the count will have to be modified later.

MERIDIAN ASTROMETRY.*

BY LEWIS BOSS, DIRECTOR OF THE DEPARTMENT.

At the annual meeting of the Trustees of the Carnegie Institution of Washington, December, 1905, an appropriation was made to enable the writer to execute the various observations and computations relating to the motions of all stars down to the seventh magnitude, including, also, all stars observed with precision during the first half of the nineteenth century. This was done with the understanding that a like appropriation would be made annually for ten years in order to complete the work under contemplated plans.

This work is essentially an extension of that for which the Institution has been appropriating annual grants to the writer during the last three years.

Associated with all such investigations of considerable extent is the thought, more or less definite, that general conclusions of more than ordinary importance may be developed as a consequence of the new knowledge to be disclosed. Sometimes the nature of the final outcome from an extensive investigation has been entirely unforeseen. It must always be regarded as a fortunate circumstance, however, when such an investigation has in view from the beginning a specific and tangible object, the attainment of which will alone constitute a sufficiently useful result to justify the effort involved in its attainment. The present investigation has such an object.

The Department of Meridian Astrometry is designed to give an impulse to the study of stellar motion. In order to do this effectively it aims to be critical as to the motions themselves and comprehensive in its field of operations. In these two aspects of its work there are natural limits imposed by questions of practicability. For more than one reason it is desirable that the investigations shall cover stars down to the seventh magnitude. Investigators and practical observers in various lines are continually desirous of information as to the positions and motions of stars of this class. It is desirable that in this age of the scientific world we take account of stock as to the vast effort which has been expended in precise observations of star-positions. The class of stars we are considering has constituted the field of such effort. It would be interesting to see what can be learned from a study of accurately determined motions of from 15,000 to 20,000 stars in relation to which the accumulated material of observations is of greatest weight.

The point which should be held clearly in mind is that the first requisite in the program of the Department of Meridian Astrometry is to ascertain what are the systematic secular motions of the stars in general. There are

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* Report for the year ending September 30, 1906. Grants Nos. 319 and 368. $28,000. *Study of motion and structure of the stellar system.* (For previous reports see Year Book No. 2, p. XVIII; Year Book No. 3, p. 85, and Year Book No. 4, pp. 78–82.) Grant No. 368, for $20,000, was not used during the year.

such motions and they can be classified to some extent as to origin, if not as to their full meaning. As a rule the total amount of such systematic motions amounts to only a few seconds during a century; but in the investigations by which motions for each star are ascertained, and through which organized motion may be recognized, it is of the first importance to get rid of the systematic errors of observations which tend to neutralize or exaggerate our estimate of the motions that actually exist. We must attempt, so far as we can, to free the measurements of star-positions from their systematic errors.

This task has occupied close attention here for several years past. The result has been full of encouragement. Various tests, some of them unforeseen, indicate that the adopted corrections are probably fair approximations to fact.

It should be understood that more or less work of this nature is going on here all the time, and that perfecting the tables of systematic correction for some of the star-catalogs of greater extent (though often of minor accuracy) has absorbed the efforts of a considerable percentage of our computing force during the past year.

In the Preliminary General Catalog we now have effective means for extending computations of systematic correction to minor star-catalogs and lists that contain few observations of so-called standard stars. We shall thus add to our resources much valuable material not hitherto available in our deduction of proper motion. Much of this dates back forty years or more, and will be specially useful.

At the same time, we carefully distinguish between systematic corrections and the effects of errors of observation that are really nothing else than fortuitous accumulations of error. Each case must be considered on its own merits, and must be subjected to adequate tests and checks sufficient to indicate the real nature of differences between the standard and the catalog of observation.

For several good reasons our discussion must also apply to as many stars as practicable. The discussion of systematic motions of the stars implies selection and discrimination as to objects. For instance, if we wish to determine whether the constants of solar motion are the same or different for different spectral types of stars, the total number of available stars must be divided into different classes, and the value of our conclusions will largely depend upon sufficiency of numbers of stars in each class. We shall probably find, for instance, that the few stars of the Orion type, as well as those of Class IV, indicate a low angular velocity of solar motion, as if those stars are either at a relatively great distance or as if their general drift is approximately parallel to the motion of the sun. At any rate, we shall find it necessary to deal with all available examples of these two classes of stars, and it will appear that even the entire number may be insufficient for a thoroughly satisfactory conclusion in respect to them.

But aside from considerations of classification, large numbers of objects are desirable in order to eliminate the purely fortuitous elements of motion. In the attempt to secure the effect of pure parallactic motion of the stars in any selected area of sky, the number of stars required to practically eliminate accidental errors in the data of computation is small in comparison with that which is required for effective elimination of the effects of random motion, complicated as it is by numerous instances of star-drift in various localities all over the sky.

Our work necessarily includes not only research upon, and assimilation of, results of observation in the past, but also a strong contribution of observations now. Other things being equal in measuring motions, observations at the two extremes of the interval in time—the oldest and the latest—are the most valuable. Therefore, reobservation of stars most in need of redetermination at the present time forms an important feature of our program.

Early in the progress of the work now going on at the Dudley Observatory it was seen that the most important obstacle to successful prosecution of work in deriving motion for the stars lay in the difficulty of computing such motion with sufficient accuracy for the southernmost one-fourth of the sky. This difficulty can be remedied only through further observations.

The distinctive feature of the further work as now authorized is found in the project for meridian observation of the stars of the southern hemisphere not accessible to exact observation at observatories in the northern hemisphere. To carry out this part of the program provision has been made to transport to some suitable site in the southern hemisphere the meridian circle belonging to the Dudley Observatory. The trustees of the Dudley Observatory, at their annual meeting of the present year, formally sanctioned this proposed use of the instrument, and in other respects have placed the resources of the observatory at the disposal of this Department of Meridian Astrometry.

The use of this meridian-circle alternately in the two hemispheres is designed to take advantage of the combination of observations made at Albany with those to be made at the selected southern station with a view to securing greater accuracy in the systematic, or fundamental, sense. The plan is to continue fundamental observations here until some time in 1908, then to set up the instrument at a southern station to be occupied for about three years, and, again returning the instrument to Albany, to complete the corresponding series of observations here. The distance from the north to the south pole being, necessarily, exactly 180°, it follows that if the minute systematic errors of measurement of the instrument remain the same for its use in the two hemispheres they will precisely eliminate for observations at or near the equator. Nor will it be necessary to assume that the law of atmospheric refraction is the same at the two stations. A proper arrange-

ment and combination of the corresponding observations will afford accurate means for determining the amount of refraction at each station, while the customary observations of circumpolar stars at lower culmination will also afford values independent of these.

Thus a twofold advantage is anticipated from this project of observation: (1) Greater simplicity and probably greater accuracy in the fundamental determination of position for stars for both hemispheres. (2) The accumulation of observations on the southern sky to reduce the disparity between the two hemispheres in observed material now existing. This existing disparity is due to two sources. In the first place, useful observations of precision upon stars in general were undertaken later in the southern than in the northern hemisphere and are relatively far less numerous. In the second place, there are only three or four observatories in the southern hemisphere engaged in effective work of this kind, while there are at least twenty such observatories in the northern hemisphere. It should occasion no surprise that the share of observing due to the southern hemisphere is entitled to added support of an increased number of instruments and observers.

Preparations for the projected expedition are already undertaken. While the site of the southern station has not been definitively settled, much study has been devoted to that subject in years past. Finally, during his visit to this country last summer opportunity for personal conference with Mr. Walter G. Davis, chief of the meteorological service of Argentina, served materially to clear up the situation. It now seems probable that in the balance of advantages, among which must be reckoned the prevalence of clear skies, Argentina offers desirable locations for the establishment of our southern station.

Some minor equipment in instruments and accessories will be necessary, in addition to the meridian circle, and these are receiving due attention. Plans for the simple constructions required are also in preparation.

It is proposed to employ a staff of about seven persons at the southern station, of whom three, at least, should be observers of experience. Under this arrangement, and with the large number of clear nights attributed to some of the stations under consideration, 15,000 observations per annum should be regarded as a safe minimum estimate of the number of observations that it will be possible to obtain.

In the interests of the entire work both north and south an observing list of stars is in preparation which is likely to number about 25,000 objects. Of these at least 8,000 to 9,000 will belong to that part of the sky to be covered by operations at the southern station.

Meanwhile the observations and computations requisite to the preparation of the Preliminary General Catalog, as described in previous reports, is in progress. As heretofore explained, this catalog will contain the computed positions for 1900 and the motions for something over 6,000 stars, including

with other stars all those that are readily visible to unassisted vision from the north to the south pole.

The greater part of the work done here during the past year has related to the various operations for completion of the Preliminary General Catalog of something over 6,000 stars, to which allusion has been made in former reports. In the interests of the entire work it has been necessary to compute first the positions and motions of several thousand stars that have been most generally and accurately observed in the last century. These results being now available, it was seen that an extension of the list to include about 2,000 additional stars would furnish a catalog essentially complete for all the stars ordinarily visible to the unassisted eye. Several hundreds of these were urgently in need of reobservation. While this reobservation would constitute something of an interruption of the regular program, it was thought to be worth while, in view of the end to be gained. Since the completion of the entire work planned for the Department of Meridian Astrometry can not well be brought about within less than nine or ten years, it seemed very desirable that practical astronomers, as well as investigators, should have the use of such a work as this Preliminary General Catalog without the delay which would be entailed by reserving publication until the completion of the entire work. This catalog might have been offered for publication a year ago if it had been restricted to the four thousand best-determined stars; but the advantage of essential completeness as to the lucid stars, and as to both hemispheres, rendered possible by the cooperation of the Royal Observatory at the Cape of Good Hope, seemed to justify the disturbance of general plan and the vigor of effort implied.

Accordingly, the positions of 740 stars of the Preliminary General Catalog have been determined by observations at the Dudley Observatory during the past year. With few exceptions, each has been observed four times, in a few instances eight times. All these observations have been completely reduced in duplicate and formed into a catalog which includes in all 1,112 stars. These results have been already incorporated in the equations which had been formed for determination of positions and motions for the Preliminary General Catalog, and within a few weeks the solution of these equations for all stars of the Catalog north of —36° should be definitive for present purposes.

As explained in my report of last year, Sir David Gill, astronomer royal at the Cape of Good Hope, has undertaken the reobservation of about 1,100 stars south of —36° of declination. Within two weeks I have learned from him that the work of observation on these stars, begun September 26, 1905, was brought to completion on August 1 of the present year. The computations are practically complete. The greater part of the results has already been received here. The cooperation of the Cape Observatory in the fur-

nishing of material for construction of the Preliminary General Catalog is of an importance which can scarcely be overestimated. Without the Cape results the Catalog would have been very imperfect for all that part of the sky that is south of —36°. As it is now there will be no blanks in the columns for proper motion. For every star of more than 6,000 to be included in the Preliminary General Catalog it is now possible to compute a value of its motion that will be a fair approximation to the truth, while the Catalog will also furnish, in nearly every instance, reliable values of right ascension and declination for 1900, with trustworthy means of bringing the positions forward for several years to come. While the primary object of this Catalog is to furnish computed motions that shall be as free as possible from systematic error, it seems probable that it will prove of considerable immediate use to practical astronomers who, for any reason, have occasion to desire accurate positions of the brighter stars at the present time. To illustrate this use, it may be mentioned that the positions for 202 stars have been furnished since the date of my last report to the United States Coast and Geodetic Survey for use in determination of latitudes. Several other requests for data concerning the motions of stars have also been received.

In accord with the estimate contained in my last report, it seems probable that the Preliminary General Catalog can be made ready for publication during the coming winter of 1906–7. The necessary computations should easily be completed before the close of the present year. The checks and scrutiny required, insuring accuracy in combination of results to produce the numbers to be printed in the catalog, will occupy an amount of time that can not be very safely predicted, especially when the duties of the staff upon other operations in the main program are considered. But it seems highly probable that the complete manuscript for the catalog can be prepared within the period already mentioned.

During the observational activity of the past year there have developed two points that have an important bearing upon an estimate of the probable quality of our current and future work of observation.

In the report of last year I called attention to two essential prerequisites for the successful combination of observations to be made in two hemispheres with the same instrument. One is that the error of graduation should be well investigated. The measurements to determine the errors of the new graduations of our meridian circle were completed a year ago, as described in the report of last year. A few months later the definitive computations were completed, and the results are available in a table of corrections giving, at intervals of 10′ for each circle, the observed corrections to be applied to the mean reading of four microscopes, in order to free that mean from the small error of graduation. Usually such determinations are carried to degrees only, sometimes to intervals of five degrees

only, and too frequently there is no attempt at all to determine these corrections. In the present instance the following facts have been made clear:

(1) That the systematic errors of our graduation, though not abnormally large, are important, and could not have been neglected without disaster to the principal aim of observations with this instrument—essential accuracy in the systematic sense.

(2) It is found that, when the corrections due to the circle-readings for each interval of 10′ are actually determined, those for intermediate divisions can be interpolated from these with the greatest confidence. The faithful periodic repetition of errors from one 10-minute interval to another is a remarkable characteristic of these circles. This fact is of great importance in its bearing upon the sufficiency of our investigation.

(3) Including the foregoing considerations, but of distinct value as a voucher for accuracy both in marking the lines by the maker and in determining their errors here, is the extraordinary similarity in the trend of errors found for corresponding subdivisions of the two circles, as well as the exceedingly minute errors found in the length of successive arcs of 10′.

I would not so dwell upon a point of technical detail like this but for the fact that it offers some assurance in advance that the execution of our proposed task is likely to be successful in one particular of primary importance, and that, too, without an undue expenditure of time and effort.

The second point relates also to a technical detail. In my report of last year allusion was made to the results of a new method applied to determine the motion of the mathematical axis of the meridian circle during rotation. As previously explained, if the observations of star-transits can be reduced to a true plane as described by the line of instrumental collimation, then the observations in the two hemispheres will offer a valuable indication of the systematic errors of each. Usually the question whether the instrumental line of collimation describes a true plane (and, if not, what are the deviations from the plane) is left most obscure as to that part of the error which may arise from minute irregularities in the form of the pivots upon which the instrument revolves.

Since the date of my last report this point has been again investigated, and in two ways. The first method employed was that to which allusion has already been made. The second did not involve any special observations, but simply treatment of observations already made in great abundance for another purpose—determination of error of graduation. The second method would have been too costly in observations if error of pivots had been the only result sought. The gratifying feature in our determinations by the two methods of this error is that the two sets of results closely agree.

These particulars as to our experience in the instrumental investigations are the only ones in that line calling for special remark at present, and these

only because of the fundamental importance of their relation to the two-hemisphere work.

So far the results of our observations of stars and of our previous computations furnishing predicted positions of the standard stars for the epoch of observation are in very satisfactory agreement. The differences, within the practicable range of observation at Albany, are very little, if any, greater, either in right ascension or declination, than those which may readily be attributed to casual errors of observation. This remarkable agreement may be partly the result of chance, a fact which can be effectively tested when we shall be in possession of results from the southern station.

The program of the coming year involves in the first line observations with the meridian circle of the Dudley Observatory at Albany. These observations are planned with special attention to their function as corresponding observations with those to be made later in the southern hemisphere. The two series north and south are to be discussed with a view to producing one integral and consistent determination of the positions of standard stars from the north to the south pole. In connection with the observations here (as at the southern station also) the observing force will be largely occupied with determinations of position for the stars of the general program, due apportionment of the objects having been made for different periods of work.

The computing force will also be occupied with preparatory works for the discussion of motion of stars for the General Catalog. This will include the preparation of ephemerides of the stars, as well as works of compilation upon various series of observations published during the last century, but which, in the present shape, have not been considered as available for use in our researches. The full extent of these latter operations can not now be foreseen. Experience must be relied upon to settle the balance of advantage, or disadvantage, between effort expended and value received; but it is certain that several series of observations now existing in the form of annual results are well worth compilation into homogeneous catalogs.

METEOROLOGY.

Bjerknes, V., and **Sandström, J. W.,** Stockholm, Sweden. Grant No. 361. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* $1,200.

The work was begun, in collaboration with Mr. J. W. Sandström, on May 1 this year, and has been continued since then without interruption.

It is expected that the first part of the treatise will be ready for print before the end of this year. In this part the methods which can be developed from the principles of hydrostatics are treated completely. These hydrostatical methods will be of fundamental importance for all that follows, which will be developed from the principles of kinematics, from the principles of hydrodynamics, and, finally, from the principles of thermodynamics.

The most important part of the work hitherto performed has been the calculation of a complete set of numerical tables to be employed by practical use of the hydrostatical methods.

NUTRITION.

Benedict, Francis G., Wesleyan University, Middletown, Connecticut. Grant No. 333. *Researches in human nutrition.* (For previous reports see Year Book No. 2, p. XXXIX; Year Book No. 3, p. 130, and Year Book No. 4, p. 258.) $10,000.

Since the last report was submitted the investigations in nutrition have dealt mainly with three problems. First, the investigations in metabolism during inanition, begun under Grant No. 258, were extended to include seven two-day experiments with fasting men in the respiration calorimeter. Three of the fasting experiments were followed immediately by one or two days with food. In all of these experiments the pulse rate, respiration rate, and body temperature, as well as the analyses of urine and respiratory products, were made. The determinations included the measurement of the heat given off from the body as well as the potential energy of the urine. A not inconsiderable portion of the time has been devoted to the preparation for publication of the extensive series of experiments on fasting. A very large number of computations have been made and their results condensed into a series of tables. The literature of the subject has been thoroughly gone over and the report is practically completed.

The second line of work taken up was a study of the effect of the ingestion of food on metabolism, a subject naturally following that of the effect of inanition on metabolism. In securing information regarding this factor of nutrition, 39 experiments varying from 8 to 28 hours in duration were made with the respiration calorimeter. Eight of them were fasting experiments of 8 hours each, carried on to get a basis of comparison with experiments in which food was ingested. In these experiments the subject was required to remain quietly seated, and every precaution was taken to elimi-

nate all muscular work and to so adjust the conditions of the experiment that the different days and different periods might be wholly comparable. The records of pulse, respiration, body temperature, and body weight were taken in all experiments, and in the majority of experiments the urine was collected in two-hour periods and the nitrogen determined. Determinations of nitrogen and heat of combustion were made in the food. The data secured by this series of experiments are to be amplified by those from others now in progress and will ultimately appear as a report.

The third line of investigation involved the development and testing of a form of respiration apparatus for obtaining the respiratory exchange in short periods. The apparatus, which is a modified form of the larger respiration apparatus, has been perfected, and check tests made with it showed most satisfactory results. On the basis of the experimental apparatus as developed, a more permanent apparatus is now being constructed. The discussion of the apparatus and check tests, as well as experiments made on man, will appear later in the form of a report.

Chittenden, Russell H., Sheffield Scientific School, Yale University, New Haven, Connecticut. Grants Nos. 264 and 348. *Study of the minimal proteid requirement of high-proteid animals.* (For previous reports see Year Book No. 3, p. 131, and Year Book No. 4, p. 259.) $3,700.

Report.—These grants have been used in ascertaining the minimal proteid requirement of healthy dogs as types of high-proteid animals. A large number of experiments on healthy dogs has been carried out for periods up to a year in length, with a study of the effects produced by a gradual diminution of proteid food, together with a diminution of non-nitrogenous food. Contrary to the oft-quoted experiments of Munk, Rosenheim, and Jägerroos, it has been found possible to keep dogs alive and apparently in good condition for a period of at least a year on relatively small amounts of proteid and with a comparatively low intake of non-nitrogenous food.

The experiments are practically concluded, the chemical work completed, but there remains to be finished a histological study of the tissues of the animals experimented with. Until the results of these examinations are known the report combining the various conclusions can not well be written. It is expected that a full and detailed report can be published this year.

Mendel, Lafayette B., Sheffield Scientific School, Yale University, New Haven, Connecticut. Grant No. 265. *Study of the physiology of growth, especially in its chemical processes.* (For previous report see Year Book No. 4, pp. 259–260.) $2,000.

Experimental work under this grant is progressing, but it will be several months before the data are compiled satisfactorily so as to admit of any general statements. The study of the changes in composition incidental to diet are temporarily completed and at present work on the chemistry and physiology of the purin bodies in embryonic life is being carried on.

Osborne, Thomas B., Connecticut Agricultural Experiment Station, New Haven, Connecticut. Grants Nos. 263 and 349. *Application of methods already developed to a comparative study of the more important vegetable proteids.* (For previous reports see Year Book No. 3, p. 111, and Year Book No. 4, pp. 260–262.) $9,000.

Abstracts of Reports: Grant No. 263 ($4,000).—Work under this grant was begun April 1, 1905, and concluded April 1, 1906. During this time a series of quantitative determinations of glutaminic acid have been made in a large number of carefully purified preparations of vegetable proteins and in some animal proteins. The results of this work have been published in the American Journal of Physiology, March, 1906, vol. xv, page 333.

The contents of this paper may be summarized as follows:

Glutaminic acid can be separated more easily in a pure state than any other decomposition product of the proteins. Experiments of our own, as well as a comparison of some of our results with those obtained by others, indicate that this acid can be separated very completely. Properly conducted determinations, therefore, have much value in showing structural differences between various protein bodies and afford the best means at present available for determining the relations of protein preparations and fractional precipitations to one another.

The various proteins examined showed a greater difference in the proportion of glutaminic acid which they yielded than has heretofore been found for any other decomposition product of these substances, with the exception of glycocoll, the higher limit for which closely approaches and lower limit falls below that found for glutaminic acid. The largest amount of glutaminic acid, 37.3 per cent, was found in wheat gliadin. This is the largest proportion of any single decomposition product yet isolated in a pure state from any protein substance. All the proteins examined yielded glutaminic acid. All the seed proteins with one exception gave more than 12 per cent.

Glutaminic acid is quantitatively the most important protein decomposition product at present known. Nearly all the plant proteins yielded much more glutaminic acid than any of the animal proteins yet examined. Proteins which yielded a large proportion of glutaminic acid likewise yielded a relatively large amount of ammonia. A strict numerical relation between the amount of glutaminic acid and ammonia does not exist. It is possible that this relation depends upon the dibasic character of glutaminic acid, since one carboxyl group may be bound in the protein molecule by a polypeptide union, while the other is united with NH_2 as an amide. It may be possible to establish closer relations between the dibasic acids and ammonia when we have accurate determinations of the quantity of aspartic acid.

The method employed for determining glutaminic acid was that of Hlasiwetz and Habermann. The glutaminic acid was separated as hydrochlo-

ride, and in most cases was obtained at once so pure that it showed the correct melting-point and composition. Only products of ascertained purity were weighed, so that the results given in the following table may be accepted as minimal. We believe that they closely represent the full quantity of glutaminic acid, though this, from the nature of the case, can not be positively demonstrated.

Proportion of Glutaminic Acid Yielded by Various Proteins.

	Per cent.
VEGETABLE PROTEINS.	
Cereals:	
Proteins soluble in alcohol:	
Gliadin, wheat	37.33
Gliadin, rye	33.81
Hordein, barley	36.35
Zein, maize	16.87
Proteins soluble in water:	
Leucosin, wheat	5.72
Proteins soluble in alkali:	
Glutenin	23.42
Legumes:	
Proteins soluble in saline solutions:	
Phaseolin, kidney bean	12.33
Legumin, vetch	16.48
Vignin, cow pea	16.89
Glycinin, yellow soy bean	19.46
Glycinin, Japanese soy bean	17.92
Conglutin A, yellow lupine	20.96
Legumes—Continued.	
Proteins soluble in saline solutions—Continued.	
Conglutin B, yellow lupine	30.05
Conglutin, blue lupine	23.00
Oil seeds:	
Proteins soluble in saline solutions:	
Amandin, almonds	23.14
Globulin, sunflower	21.79
Corylin, hazelnut	17.94
Globulin, castor bean	14.50
Excelsin, Brazil nut	12.94
Globulin, cotton seed	17.59
Globulin, squash seed	12.35
Edestin, hemp seed	14.00
ANIMAL PROTEINS.	
Casein, cow's milk	10.77
Ovalbumin, hen's egg	9.01
Conalbumin, hen's egg	7.00

This table shows that the proteins of the cereals yield much more glutaminic acid than do any of the other groups, for, omitting leucosin, which is present in the wheat kernel only in very small proportion and confined chiefly to the embryo of the seed, the average yield of this acid was 29.5 per cent, while the legumes yielded 19.6 per cent, the oil seeds 16.8 per cent, and the three animal proteins 8.9 per cent.

An examination of the literature up to the time this work was carried to this point showed that such other animal proteins as had been examined had yielded very small proportions of glutaminic acid, most of them less than 3 per cent. It seemed, therefore, that, as the proteins of the seed endosperm as well as of milk and eggs yielded relatively large quantities of this amino-acid, in contrast to the proteins of animal tissues, a distinction could be made between the *food* proteins and the tissue proteins.

With this idea in view, we undertook to determine the proportion of glutaminic acid yielded by the muscle tissue of the ox and of the fish (halibut), the results of which have shown, however, that these tissues yield about the same amount of this acid as did the three animal proteins which we had already examined.

Since this work was completed Abderhalden and Samuely * have revised their determinations of glutaminic acid in the serum globulin and serum albumin of horse blood, and give as the average of three careful determinations in each 8.5 per cent and 7.7 per cent, respectively, instead of 2.2 and 1.52 per cent, respectively, which Abderhalden formerly gave.†

In view of these later figures by Abderhalden, those published earlier by him and his colleagues for other animal proteins can not be used as a basis for a quantitative comparison, and in justice to those offering them it should be stated that they were given only as minimal quantities.

If these later figures are accepted as representing approximately all of the glutaminic acid in these proteins, it would appear that such animal proteins as have been carefully investigated yield similar proportions of glutaminic acid, namely, about 8 to 11 per cent, as may be seen from the following table:

Glutaminic Acid Yielded by Animal Proteins.

	Per cent.	
Casein	10.8	Osborne and Gilbert.
Casein	10.0	Fischer.
Casein	10.7	Abderhalden and Pregl.
Ovalbumin	9.1	Osborne and Gilbert.
Ovalbumin	8.0	Abderhalden.
Seralbumin, horse	7.7	Abderhalden and Samuely.
Serglobulin, horse	8.5	Do.
Beef-muscle protein	11.1	Osborne and Gilbert.
Fish-muscle protein	8.9	Do.

In view of the wide differences in the constitution of the proteins of the different species of seeds, as shown by the determinations of glutaminic acid given in this paper, as well as by the few quantitative determinations of the other decomposition products which have been made, it would seem important to know definitely whether or not similar differences exist between the proteins of the tissues of different species of animals which serve as food for man, for it is possible that in such differences will be found a logical basis for the use of one form of protein rather than another when dealing with nutrition in various pathological conditions. We hope to be able to follow this work along these lines in the near future.

The quantitative determinations of the decomposition products of the proteins of the wheat kernel have been completed, and the results have been published under the following title: "The chemistry of the protein bodies of the wheat kernel," Parts II and III, in American Journal of Physiology, 1906, XVII, pp. 223 and 231.

Part II described the methods used in preparing and purifying the large quantities of proteins needed for proper determinations of the decomposition

* Abderhalden and Samuely. Zeitschrift für physiologische Chemie, 1905, XLVI, p. 194.

† Abderhalden. Zeitschrift für physiologische Chemie, 1905, XLIV, p. 22, 1902–1903, XXXVII, p. 484.

products. As only the purest attainable preparations were suitable for this work, a large amount of time and labor was required for making them.

Over 80 per cent of the proteins of the wheat kernel consists of gliadin and glutenin, which, in most varieties of wheat, are present in about equal proportions. Several kilograms of each of these proteins were made and used in the work described in Part III. The remainder of the proteins of this seed are leucosin, a globulin, and a mixture of several proteoses. The combined quantity of all these proteins is only about 1 per cent of the seed, and consequently the preparation of large quantities of them would be impossible if it were not for the fact that they are constituents of the embryo and can be obtained from the commercial germ meal of the flour mills. A sufficient quantity of leucosin was prepared from this source to enable us to make a nearly complete analysis. Attempts to prepare the globulin from the germ meal failed, as we were not able to separate it from the nucleic acid, which is present in the wheat embryo in relatively large proportion. No attempt was made to prepare the proteoses, as there is no available method by which products of definite character could be obtained. The amount of these proteoses is too small to make their analysis important.

The results described in Part III are summarized as follows:

The extensive use of wheat flour makes it of great importance to know as much as possible regarding its chemistry and especially regarding the chemistry of its protein constituents. This is of importance not only in relation to problems of vegetable chemistry and physiology, as well as to problems of protein chemistry, but especially so in connection with the nutrition of man. In connection with the latter question, it has become of fundamental importance to know the nature and proportion of the products which the food proteins yield when decomposed by boiling acids, for the recent progress in our knowledge of digestion has shown that the digestive enzymes convert the food protein very largely into the same substances as those produced by boiling acids. These final products of hydrolysis are consequently the units with which the process of assimilation chiefly deals.

Furthermore, as the wheat kernel is the only seed from which practically all of the protein constituents have been isolated and of which we have the most definite knowledge both in respect to their kind and proportion, it is especially desirable to supplement our present knowledge by as full information as possible concerning the primary decomposition products of these proteins in order that something in regard to their structural relations may be known and the kind and amount of the possible products of the metabolism of this seed may be ascertained.

The investigation of this problem has accordingly been undertaken, the results of which are given in the following pages.

As stated in Part II of this series of papers, gliadin, glutenin, and leucosin were the only proteins of the wheat kernel which could be obtained in

sufficient amount for such quantitative estimations of their decomposition products.

The determinations of the mono-amino acids have been made for the most part according to the methods recently proposed by E. Fischer (Zeitschrift für physiologische Chemie, 1901, XXXIII, 151) and those of the bases essentially according to the methods given by Kossel and his associates (Kossel and Kutscher, *ibid.*, 1900, XXXI, 161; Kossel and Patten, *ibid.*, 1903, XXXVIII, 39). The general plan of these analyses has been that followed by Abderhalden (*ibid.*, 1903, XXXVII, 484) in analyzing oxyhemoglobin.

In carrying out this work care has been taken to make the identification of the substances determined as complete as possible and to weigh only such products as examination showed to be essentially pure, so that the figures given in the following table are to be taken as minimal, except possibly those for prolin, which may be slightly too high owing to the well-known difficulty of separating *all* of the other amino-acids from its alcoholic solution.

The results of these analyses are given in the following table:

	Gliadin.	Glutenin.	Leucosin.
	Per cent.	*Per cent.*	*Per cent.*
Glycocoll	....	0.88	0.73
Alanine	2.00	4.64	4.45
Amino valerianic acid	.21	.24	.18
Leucine	5.61	5.95	11.34
*a*Prolin	7.06	4.23	3.18
Phenyl alanine	2.35	1.97	3.83
Aspartic acid	.58	.91	3.35
Glutaminic acid	37.33	23.42	6.73
Serine	.13	.74	....
Tyrosine	1.20	4.25	3.34
Cystine	.45	.02	....
Oxyprolin	....	....	....
Lysine	0	1.92	2.75
Histidine	.61	1.76	2.83
Arginine	3.16	4.72	5.94
Ammonia	5.11	4.01	1.41
Tryptophane	Present.	Present.	Present.
Total	65.81	59.66	50.06

The analyses show that these three proteins are distinguished from one another by differences so great that there can be no question that decided differences in structure exist between them. Thus gliadin differs from glutenin and leucosin by yielding no glycocoll and lysine and much more prolin and glutaminic acid. Gliadin and glutenin each yield very much more glutaminic acid and ammonia than leucosin, and less leucine. In respect to the amount of these amino-acids, leucosin more nearly resembles the animal proteins than the seed proteins thus far examined, and in this connection it is interesting to note that leucosin occurs chiefly if not wholly

in the embryo of this seed and is probably one of its "tissue" proteins, in contrast to the "reserve" proteins of the endosperm, of which gliadin and glutenin form the chief part.

Glycocoll is not given among the products of hydrolysis of gliadin, for careful efforts to detect its presence in the preparation used for this analysis failed. Another hydrolysis of another lot of gliadin prepared in essentially the same way did yield 0.02 per cent of glycocoll whose identity was certainly established. This small quantity was most probably due to a small admixture of glutenin in the gliadin used for this determination, which may have been dissolved in very small amount by the large quantity of dilute alcohol used for extracting the gliadin. A contamination of this preparation with 2 per cent of glutenin would have sufficed to give the amount of glycocoll found. The amount of prolin yielded by gliadin is larger than that as yet obtained from any other protein, those coming nearest being the albuminoids spongin and gelatin. As the amount of prolin from glutenin is relatively high, the wheat proteins as a whole, so far as we yet know, are particularly rich in this peculiar amino-acid.

Glutaminic acid is the chief constituent of the endosperm proteins of this seed, gliadin yielding more of this acid than any protein yet examined and very much more than the average of our food proteins. The average amount of glutaminic acid from the total protein matter of this seed is more than 30 per cent. The yield of ammonia is likewise relatively very high, more than 4.5 per cent for the total protein, while the aggregate amount of hexone bases is correspondingly small. In respect, therefore, to the proportion of several of their decomposition products the wheat proteins present marked and important differences from other food proteins.

During the year in which work under this grant was carried out it has been necessary to devote a great deal of time to studying the methods employed and assuring ourselves of the accuracy of our work. As a great many processes were used this has necessarily delayed the work of the first year, for many of these processes require a long time for their execution as well as great care. The experience which we have acquired has now put us in a position to obtain results much more rapidly.

Grant No. 349 ($5,000).—Under this grant work has been continued along the same lines as under Grant No. 263. Large quantities of protein preparations have been made and are now ready for hydrolysis. These include several from leguminous seeds, nuts, and oil seeds. A complete quantitative analysis of the decomposition products of phaseolin, the principal protein of the white or kidney bean, has been made and the results will soon be published. A similar analysis of excelsin is well advanced.

A study of the methods for the quantitative determination of the basic decomposition products of proteins has been made and the bases determined in several proteins, the results of which we expect to be soon able to publish.

PALEONTOLOGY.

Hay, O. P., American Museum of Natural History, New York, N. Y. Grant No. 118 (supplement). *Completion of a monograph on the fossil turtles of North America.* (For previous reports see Year Book No. 2, p. XXXVII; Year Book No. 3, p. 122, and Year Book No. 4, p. 241.) $1,800.

The monograph of the fossil turtles of North America is completed and it is expected that the manuscript will be presented soon for publication. The investigation has required much more time than was originally anticipated. In this monograph there are described 251 species, of which about 75 are new. In addition to the discovery of new species our knowledge of many species described by Leidy, Marsh, and Cope has been greatly extended by the finding and study of much additional material. The species are illustrated by about 1,000 drawings and photographs.

PHILOLOGY.

Flügel, Ewald, Stanford University, California. Grant No. 244. *Preparation of a lexicon to the works of Chaucer.* (For previous reports see Year Book No. 3, p. 96, and Year Book No. 4, p. 242.) $7,500.

The preparatory work has progressed favorably during the past twelve months and will be completed before next summer. The work itself is divided into six groups.

(1) *Revision and completion of the slips.*—The revision of the slips written for the Canterbury Tales has occupied Dr. Wildhagen, Mr. Hübschmann, and Mr. Wolderich during the past year. Dr. Flügel has carefully revised their work and registered the variants of the eight manuscripts printed by the Chaucer Society (for publication in Anglis). The work on the slips from the Canterbury Tales is now finished.

The revision of the slips written for the Astrolabe has been commenced by Dr. Wildhagen. Dr. Flügel will make a final revision and add the results from his new collation of two Oxford manuscripts.

Mr. Rössger, Mr. Hübschmann, and Mr. Wolderich have been engaged on the slips for the Minor Poems and have finished "The Parliament of Fouls" and "The House of Fame." The "Legend of Good Women," commenced by Miss Mason, is being revised by Mr. Wolderich. Mr. Moll has finished his revision of four books of "Troilus" and is at work on the fifth.

Mr. Rössger is to commence (about October 1) with "Boethius," utilizing the results of the Old French "Boece," a transcript of which has now been obtained. The Old French parallels are to be copied on each slip.

Every slip written by these assistants is being revised carefully by Dr. Flügel.

(2) *Alphabetizing of the revised slips.*—The slips revised during the past year were assorted into a "rough" alphabet by Mr. J. Rubin, Mr. Wolderich, and Mr. Rössger. They have finished the alphabet for the Canterbury Tales, with the exception of the "Wife of Bath."

(3) *Copying for the collateral apparatus.*—Mr. Tanneberger has been working on copying the words underlined in Froissart; he has besides assorted the words collected from the "Roman de la Rose" into an "exact alphabet," preparing what is practically a concordance to this work, which will prove most valuable for the Chaucer Lexicon.

(4) *Copying of Old French texts (unpublished) of authors known to Chaucer.*—Mr. François Bruel, of Paris, has finished his copy of "Boece," and is to continue with his copying from Machault. Dr. Padelford has copied one manuscript of the Old French "Melibee" at London. Dr. Flügel has collated this copy with the manuscript and added collations from twelve other manuscripts at London and Paris. The whole is to be edited in a parallel text edition with Chaucer's translation.

(5) *Work on certain articles for the Dictionary in its final shape.*—Professor Einenkel has continued his work on the prepositions, the "impersonalia," and the auxiliary verbs.

(6) *The work of verification of the accuracy of printed texts* has been carried on at London by Miss H. Palmer, who has carefully collated one manuscript of "Troilus" and one manuscript of the Canterbury Tales (the Lansdowne manuscript). Mr. Arthur Rogers, of the Cambridge University Library, has been engaged on a collation of the Cambridge Boethius manuscripts; Dr. Flügel has collated the Astrolabe manuscripts at Oxford and verified a large number of doubtful passages from manuscripts at Oxford, London, Cambridge, and Paris.

PHONETICS.

Scripture, E. W., New York, N. Y. Grant No. 358. *Completion of a work on researches in experimental phonetics.* (For previous reports see Year Book No. 2, p. XL; Year Book No. 3, p. 114, and Year Book No. 4, pp. 243, 244.) $1,800.

The first volume of results, for which the manuscript was completed in 1905, has been published as a quarto volume of 202 pages with 13 plates and 138 figures (Publication No. 44 of the Carnegie Institution of Washington). The manuscript for another volume is well advanced. The topics treated in the second volume will include records known as the Yale, Mitchell, Depew, Graham, and Yvetot records.

PHYSICS.

Barnett, S. J., Tulane University, New Orleans, Louisiana. Grant No. 149. *For determining whether an electric intensity is developed in a dielectric, moving at right angles to a magnetic field.* (For previous reports see Year Book No. 3, p. 124, and Year Book No. 4, p. 245.) $250.

Experimental work has been in progress for some time, and will, it is hoped, be completed before the end of the present academic year.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 292. *The ionization and nucleation of atmospheric air, natural and dust-free.* (For previous report see Year Book No. 4, pp. 246–247.) $1,000.

The chief purpose of the volume recently submitted to the Institution for publication is the development of the fog-chamber of simplest practical character capacious enough to admit of the measurements of the largest available coronas and efficient up to the highest exhaustions applicable—*i. e.*, those which do not uselessly overstep the optical limits of the experiment where fog particles become so fine as to be virtually inactive in diffracting or scattering white light. This seems to have been accomplished, and the results, so far as they go, are in no way inferior to the accomplishments of Wilson's piston apparatus. It has not, however, been possible to go much beyond the large green-blue-purple corona. The forms beyond are filmy so and nearly colorless as to be unsuitable for measurement, but the steam jet nevertheless reveals a whole order of axial reds, oranges, and yellows lying beyond which have not been detected in any form of fog-chamber whatever.

As used in most experiments, including the author's own earlier work, the fog-chamber with plug stopcock seems to be of very inferior efficiency as compared with the piston form. This, however, in a properly manipulated apparatus is the case only when the attempt is made to measure the drop in pressure isothermally at the fog-chamber, closed at once after exhaustion. The datum must be computed from the initial pressures of the fog and vacuum chambers, their final pressures when in contact (always at the same temperature), and their volume ratio. Though some correction would be anticipated, one would not be prepared for the large difference between the apparent isothermal drop and the true drop as actually appears. In the experiments of the volume the relation is fully 100 to 77, a difference of nearly 25 per cent. Hence it will be necessary to restandardize the coronas with this result in view, an undertaking in which the author is now engaged and which the large number of other subsidiary results that have since accrued would alone have made desirable.

Having improved the fog-chamber, it was made use of in certain incidental experiments. The author has already shown that in case of the persistent nuclei produced by intense X-radiation distribution of nuclei within the fog-

chamber is a most remarkable feature of the exposure. The same, however, is true of the ions. Whether produced by X-rays or by radium acting from long distances, the density of ionization is, as a rule, different in different parts of the fog-chamber, showing the important effects due to secondary radiation. In like manner the change in nucleation produced when the exciting cause (X-ray bulb or radium tube) recedes to different distances from the fog-chamber is of interest. For the non-inclosed bulb the decrease of nucleation is slower than the first power of distance. It is faster for the bulb inclosed in a windowed lead chamber, faster still if the window is closed by a thin tin plate, but in no case does it approach the law of inverse squares.

Finally, if the rate of decay of the ions can be inferred from the electrical method, a method for the standardization of coronas is presented which bids fair to be the most satisfactory solution of the problem suggested. The method admits of the determination not only of the relation of the nuclei corresponding to a given case to two different coronas (cæt. par.), but of the absolute nucleation involved as well, not to speak of the possibility of detecting in this way how a given mass of precipitated water is distributed among nuclei of different sizes—one of the most important of the problems outstanding in connection with the subject.

The volume adduces a variety of results for colloidal nuclei in media other than air-water. It is shown, for instance, that there is no evidence to prove that the colloidal nuclei in a medium of carbon dioxide and water are larger than in the other case, in spite of the presence of the coercible gas in the latter, in which groups of larger molecular aggregates would be anticipated. On the other hand, large colloidal nuclei do seem to occur in the medium of alcohol and air, wherefore it is suggested that the colloidal nuclei of dust-free wet air are primarily to be associated with the saturated vapor, and that the gas enters as a secondary factor.

Furthermore, a systematic comparison between the number of ions in the atmosphere and the corresponding dust contents in the lapse of time is worked out under the author's direction. No relation is apparent; whence it follows that as the nucleation is largely of local origin other sources must be looked to for the ionization, or that the enormous local contributions to the ionization of a given region (due to combustion, etc.) vanish so rapidly as to be quite negligible. Incidentally, the nucleation of the atmosphere of Providence during nearly four years is exhibited.

Finally the author returns to the inquiry, already begun elsewhere with negative results, whether there is any time change in the colloidal nucleation of dust-free air, such as might be ascribed to the ionization produced by penetrating cosmical radiation coming from without; for it was to be the plan of these researches to begin with the study of the ordinary dust contents in its dependence on time and thereafter to continue in the same way with the filtered atmosphere. The apparent nucleation of dust-free air is found

to increase synchronously with the decrement of the barometer. But as the amount of adiabati ccooling, *i. e.*, the efficiency of the apparatus (cæt. par.) follows the same conditions, it is extremely difficult to disentangle the two effects.

Burgess, Charles F., University of Wisconsin, Madison, Wisconsin. Grant No. 330. *Investigation of the properties of electrolytic iron and alloys made from it.* (For previous report see Year Book No. 4, pp. 247–249.)
$2,500.

Abstract of Report.—The work has progressed without interruption during the past year, being under the charge of Dr. O. P. Watts, who has devoted his entire time to it. Acknowledgment is made of assistance received from Profs. G. C. Shaad and A. Hoyt Taylor, of the University of Wisconsin; from Mr. Andrew A. Blair, of Philadelphia, Pennsylvania, and Prof. R. E. Lyons, of the University of Indiana.

About 1,500 pounds of electrolytic iron have been taken from the tanks during the past year, being used in large part for the preparation of alloys. A stock is being accumulated for second refining.

Some disappointment has been encountered in not being able to turn out an iron by single refining of as high a degree of purity as the analyses a year ago led us to believe might be readily attained. Difficulty has been experienced in securing concordant analyses, due largely to the very small percentages of the various impurities. Much remains yet to be done on the chemical analysis of electrolytic iron, especially in reference to gaseous elements. The following figures are typical of what is being accomplished in the matter of purity under present conditions of operation:

	AA. Double refined.	A. Single refined.	B. Ingot turnings from A.
Sulphur	None.	0.001	0.012
Silicon	0.013	.003	.096
Phosphorus	.004	.020	.025
Manganese	None.	None.	.002
Carbon	.012	.013	.047
Hydrogen	.072	.083	.083

It is shown that a second refining improves the purity. The above figures indicate the necessity of further study to explain the apparent increase in silicon by a second refining, to confirm the apparently demonstrated fact that the hydrogen may still be retained in the metal after being melted, and to determine what factors govern the addition of impurities during the melting process.

Much attention has been given to the matter of melting the electrolytic iron, and this involved a study of refractory materials. The method of

melting now in use is described in Electrochemical and Metallurgical Industry for July, 1906, by Dr. O. P. Watts.

A large number of alloys and ingots of iron have been prepared, and these have been forged and machined for test bars for examination of physical properties. These tests are not sufficiently advanced to enable them to be reported.

The following publications deal with various phases of the work carried on during the past year:

Structure of electro-deposits. By C. F. Burgess and O. P. Watts. Trans. Amer. Electrochemical Soc., vol. IX, 1906.

Peculiarities of physical structure of iron deposits are discussed, and the resemblance is shown between electrolytic iron deposits and deposits of various minerals formed in natural processes.

Observations on the corrosion of iron by acids. By C. F. Burgess and S. G. Engle. Trans. Amer. Electrochem. Soc., vol. IX, 1906.

It appears that the physical structure, perhaps more than the purity, influences the rate at which iron corrodes. It is shown that unheated electrolytic iron dissolves in dilute sulphuric acid at a rate greater than does zinc, and this fact, together with the greater purity of the resulting hydrogen, appears to make electrolytic iron a useful material for hydrogen generation.

An electric furnace for heating crucibles. By O. P. Watts. Electrochemical and Metallurgical Industry, July, 1906, p. 273.

Iron and Calcium. By O. P. Watts. Journal of American Chemical Society, Sept., 1906.

It is shown that it is difficult, if not impossible, to alloy calcium with iron, at least without the aid of some other element. It does not appear practicable to employ calcium for the removal of phosphorus from molten iron.

Magnetic properties of electrolytic iron. By C. F. Burgess and A. Hoyt Taylor. Trans. Amer. Inst. of Electrical Engineers, vol. XXV, 1906.

The remarkable influence of heating on the magnetic properties of electrolytic iron is shown. Curves are given indicating the magnetic properties.

Limitations of the ballistic method for magnetic induction. By A. Hoyt Taylor. Physical Review, vol. XXIII, No. 2, August, 1906.

In studying the magnetic behavior of an electrolytic iron ring it was found that serious discrepancies occurred when different methods were employed. It was found that a large error was introduced by the step-by-step method, an error which, while present in other forms of soft iron, is especially noticeable in the electrolytic iron tested. This error was found to be due to the magnetic viscosity, and the above paper describes a modified ballistic method of measurement which was devised by the author to eliminate the error ordinarily introduced by this property.

Campbell, William, Columbia University, New York, N. Y. Grant No. 179. *Study of the effect of heat treatment upon the microstructure and physical properties of steel and iron.* (For previous reports see Year Book No. 3, p. 124, and Year Book No. 4, p. 249.) $1,500.

Abstract of Report.—The work of last year has been continued by the examination of the series of high-carbon steels (0.7 to 2.0 per cent carbon) after quenching from temperatures between 600° and 1400° C. A series of 18 steels, carbon 0.1 to 1.5 per cent, is being investigated as to overheating and refining by heat treatment.

Six weeks have been spent at a large iron and steel plant, studying, for the most part, the finishing temperatures of structural and rail steel with a Wanner optical and a Le Chatelier thermo-electric pyrometer. The average finishing temperature for 85-pound rails was 1105° to 1145° C., for 8-pound rails 1050° to 1100° C., for low-carbon structural steel of small dimensions about 985° C. The number of temperature readings obtained was very great indeed, and numerous specimens were saved for further investigation along microscopic lines.

Carhart, Henry S., University of Michigan, Ann Arbor, Michigan. Grant No. 151. *Determination of the electromotive force of Clark and Weston cells, etc.* (For previous reports see Year Book No. 3, pp. 124–126, and Year Book No. 4, p. 250.) $500.

Abstract of Report.—During the summer and autumn of 1906 five series of determinations of the electromotive force of the Weston normal cell have been made in conjunction with my colleague, Prof. George W. Patterson. The apparatus used was the absolute electrodynamometer described by Patterson and Guthe in the Physical Review, vol. 7, p. 257, and by Guthe in the Bulletin of the Bureau of Standards, vol. 2, No. 1, p. 33. Our instrument differs from the one described by Guthe chiefly in the fact that the suspending bronze wire is about two and a quarter meters long as compared with one of about one-third that length used by Guthe.

The current measured by the electrodynamometer is measured simultaneously by means of a standard resistance and a Wolff's potentiometer, assuming a value of the electromotive force of a Weston standard cell set up about three years ago. Then the ratio of the current measured by the electrodynamometer and the apparent current measured by the standard resistance and the potentiometer is the same as the measured electromotive force and the electromotive force assumed.

The results for the five series must be taken as preliminary only. The elaborate calculation to find the correction for the irregularities of the winding of the stationary coil has been gone over but once. It must be recalculated as a check. Further investigation of the period of the suspending wire

and its attached cylinders must be made, especially as regards any change of period that may occur. Corrections for temperature have been applied, but these should be checked. Then additional series will be made for a final determination.

In the table the word "chemical" refers to the check cell in which the mercurous sulphate used was made by chemical precipitation; "electrolytic" designates cells with electrolytically prepared mercurous sulphate.

Series.	Chemical.	Electrolytic.
1	1.01862	1.01842
2	1.01864	1.01844
3	1.01876	1.01856
4	1.01864	1.01844
5	1.01867	1.01847
Means	1.01867	1.01847

These values are for the temperature 20° C.

This mean value for cells made with electrolytically prepared mercurous sulphate is 6 parts in 100,000 lower than the one found by Guthe, as given in his final report in the Bulletin of the Bureau of Standards, vol. 2, No. 1.

Franklin, W. S., and **Freudenberger, L. A.,** South Bethlehem, Pennsylvania, and Newark, Delaware. Grant No. 344. *A new method of measuring electrolytic resistances.* $250.

This grant was for the purpose of construction of apparatus during the summer of 1906. Dr. Freudenberger reports that this preliminary work has been done, showing that the alternating current galvanometer possesses excellent working characteristics for the purpose of measuring electrolytic resistances.

Lewis, E. Percival, University of California, Berkeley, California. Grant No. 150. *Photographic investigations of vacuum-tube spectra of gases and vapors.* (For previous reports see Year Book No. 3, p. 128, and Year Book No. 4, p. 253.) $500.

The large quartz spectrograph provided for by this grant has been completed and adjusted for work, and a description of the instrument has been published in the Astrophysical Journal for June, 1906. At present a series of investigations on vacuum-tube spectra is being carried on with the particular object of ascertaining the relationship between the nature of the electric discharge and the accompanying differences observed in spectra. It is hoped that some results will shortly be ready for publication.

Nichols, Edward L., Cornell University, Ithaca, New York. Grant No. 286. *Quantitative study of fluorescence and phosphorescence, especially at low temperatures.* (For previous report see Year Book No. 4, p. 254.) $1,000.

Report.—Investigations have been in steady progress by Professors Nichols and Ernest Merritt. The substance known as Sidot blende, a fluorescent zinc oxide, which seems to be especially well suited to bring out the relationships that exist between different types of luminescence, has been made a subject of detailed study. The luminescence of Sidot blende when excited by Roentgen rays was carefully studied with the spectroscope, and the results were compared with the photo-luminescence of the same substance during excitation by means of the light of the carbon arc. To determine the validity or failure of Stokes's law a pure spectrum from the arc light was obtained by the method of double dispersion, and it was found that luminescence could be excited by light of wave-lengths lying between points $0.47\,\mu$ and $0.497\,\mu$, whereas the phosphorescence spectrum could be followed to wave-length $0.46\,\mu$. It appears, therefore, that there is a violation of Stokes's law similar to that already noted in the case of similar fluorescent substances.

These experiments were followed by a careful study of the law of decadence of the phosphorescence spectrum of Sidot blende, wave-length by wave-length. It was found that the phosphorescence spectrum remains unaltered during decay as regards the distribution of intensities, the rate of decay of the various wave-lengths being the same. A preliminary account of these experiments was published in the Physical Review * for October, 1905.

This work was followed by an extended series of experiments upon the law of decay of the phosphorescence of Sidot blende, a subject of considerable importance to the general theory of luminescence. Experiments were first made upon various wave-lengths of the phosphorescence spectrum, measurements of the brightness of each region being made by means of the spectrophotometer as a function of the time which had elapsed after the close of excitation. It was found that the results could be closely represented by an expresssion of the form

$$1 / \sqrt{I} = a + bt$$

where a and b are constants.

A preliminary account of these experiments was published in the Physical Review † for May, 1906, in which paper the bearing of the relation determined upon theories of luminescence is discussed at considerable length.

In these measurements it is possible to extend observations only over a brief period of time—about seven seconds. Early observations of the decay of phosphorescence of other substances, taking the phosphorescent light as a

* Physical Review, vol. 21, p. 247. † Physical Review, vol. 22, p. 279.

whole, have been made by E. Becquerel and others, and their results show a more complicated relation than that which we have found.

Since the law of decay for various wave-lengths of the phosphorescence spectrum is the same, it was possible to apply our method with some modifications to the undispersed light, and thus to greatly increase the interval of time under observation.

By means of a specially devised photometer used in connection with a chronograph we have made an extended study of the decadence of the phosphorescence from calcium sulphide, Sidot blende, willemite, and other phosphorescent materials under a variety of conditions. The interest and novelty of the results thus obtained was such as to lead us to spend a great portion of the year on this phase of the subject and to plot hundreds of decadence curves. The decadence of phosphorescence is in fact a somewhat complicated phenomenon, depending upon the length, intensity, and character of excitation and likewise upon the previous history of the substance. The emission of light after excitation appears to result from two independent processes, one of which succeeds the other after a fixed interval of time. The law of the two processes is the same, being that determined in our earlier experiments, but the constants of the equation for the relation between time and intensity of light are different. The effect of increasing the intensity of excitation on the one hand or of prolonging the duration of a weak excitation upon the other is to produce saturation somewhat analogous to that observed in the magnetization of iron and even an effect which might be termed hysteresis. The results of these further studies of the decay of phosphorescence have been given in a paper printed in the Physical Review* for July, 1906.

The remarkable effect of certain of the longer wave-lengths of the spectrum, particularly of the red and infra-red regions, upon phosphorescence is likewise under investigation. A mass of interesting results has been obtained, and the experiments, which were interrupted for a time by the removal of the Department of Physics to its new laboratory, are again under way. The preliminary report upon this portion of our subject was made at the July meeting of the Physical Society.

Apparatus for a thorough investigation of fluorescence and phosphorescence under the action of the cathode rays has been purchased from money made available by this grant, and the experimental work will be taken up as soon as the study of the effect of the infra-red is completed.

Under the direction of Professors Nichols and Merritt a graduate student, Miss Frances G. Wick, has made a careful spectrophotometric examination of the optical properties of a typical fluorescent solution and a much more thorough and systematic study of the phenomenon of fluorescence absorption than had hitherto been attempted. This phenomenon, the existence of

*Physical Review, vol. 23, p. 37.

which in the case of uranium glass was discovered by Burke, was subsequently investigated in much greater detail in the case of fluorescent liquids by the present writers. In two recent papers Carmichel has denied the existence of this phenomenon, but Miss Wick's measurements not only serve to establish it, but afford an admirable quantitative study of the relations involved. Her results will be incorporated in a final report to the Carnegie Institution of Washington. Directly connected with the subject of fluorescence absorption and dependent upon it is the increase of conductivity of fluorescent liquids when under excitation, a phenomenon which was discovered and described in an early portion of this investigation. This phenomenon has likewise been questioned by Carmichel, and arrangements have been made with another graduate student, Mr. Percy Hodge, to repeat the measurements upon this interesting subject. His results will likewise be published in a final report.

Preparations are at present being made for an extended investigation upon the effect of high and low temperatures upon the position and intensity of the fluorescence bands in the spectra of solids.

Wood, Robert W., Johns Hopkins University, Baltimore, Maryland. Grant No. 248. *Researches on the theory of light.* (For previous reports see Year Book No. 2, p. xxxix, Year Book No. 3, p. 128, and Year Book No. 4, pp. 255–257.) $1,000.

THE COMPLEX FLUORESCENCE SPECTRUM OF SODIUM VAPOR AND ITS ANALYSIS.

The study of the remarkable fluorescent spectrum of the vapor of metallic sodium has been continued. The very complicated spectrum observed when the vapor is illuminated with white light is being gradually dissected by stimulating the medium with the monochromatic radiations from the electric arcs between metal electrodes. The lamps of fused quartz made by Heraeus, of Hanau, have been found most satisfactory, but unfortunately very few metals can be used with them. For every type of monochromatic stimulation we obtain a definite fluorescent spectrum, consisting usually of sharply defined lines, spaced at nearly regular intervals measured along a normal spectrum, both of longer and shorter wave-length than that of the exciting light. The same series of lines can be obtained by excitation of various points of the spectrum, providing that these points coincide in position with the lines of the series. The series is not, however, always complete. For example, if we excite the vapor with the blue cadmium line of wave-length 4799, we obtain a series which is broken up into groups of two and four lines, owing to the absence of certain lines. These missing lines can be detected in their proper places by very long exposures, the complete set being made up of lines almost exactly equally spaced along the spectrum. One of these lines coincides in position with the line 5209 of the silver arc, and when the fluo-

rescence is stimulated with light of this wave-length the same series is obtained as before, but with the difference that now the lines are of uniform intensity—*i. e.*, the series is not divided into groups by the absence of lines. Stimulation with the green cadmium ray gives a fluorescence spectrum consisting of a number of close double lines regularly spaced along the spectrum, and characteristic spectra have been obtained with a large number of monochromatic stimulations. Thus far results have been obtained with the following sources of light: Vacuum tubes containing helium and hydrogen, quartz arc lamps containing zinc, cadmium, and thallium, and ordinary arcs between copper, lead, silver, bismuth, lithium, and barium electrodes. The stimulating radiations are separated and utilized by employing a large bisulphide prism and a long-focus telescope objective. Exposures of ten hours are often necessary, and the metallic arcs require constant attention. The lines are now being measured and the spectra compared, and it is hoped that the results will throw considerable light upon the mechanics of molecular radiation. Over 100 lines are present in the fluorescent spectrum excited by the zinc arc. This appears to be the first case in which it has been possible to completely dissect a complicated spectrum into the comparatively simple spectra of which it is composed, by shaking the individual electrons one at a time and noting the effect upon other electrons in the same group.

CATHODE LUMINESCENCE OF SODIUM VAPOR.

This luminescence was first observed by Lewis in a glass vacuum tube, but its spectrum has never been photographed or studied. By employing a steel vacuum tube containing metallic sodium heated red hot and furnished with a large concave electrode of aluminum a blazing disk of yellow light appeared at the point where the cathode rays came to a focus. The spectrum could be photographed easily through the window of plate glass which closed the end of the tube. It was found to consist of the doublets of the principal and subordinate series, and in addition the complete fluorescent spectrum of the vapor as it appears with white light stimulation. The cathode rays are thus capable of exciting the electrons concerned in the production of the fluorescent spectrum, which remain quiescent when the metal is burnt in the Bunsen flame, electric arc, or introduced into the ordinary vacuum tube.

THE MAGNETIC ROTATION, TEMPERATURE EMISSION, AND FLUORESCENCE SPECTRA OF IODINE.

The discovery was made last year that the vapors of sodium and iodine, when placed between crossed Nicol prisms in a powerful magnetic field, transmit light which the spectroscope shows as a bright line spectrum. In the case of the vapor of sodium these lines were photographed with the 15-foot concave grating, and were found to coincide with certain lines of the fluorescent spectrum. Many of the fluorescent lines are absent or very

faint, which shows that the power of rotating the plane of polarization of the transmitted light is only possessed by certain electrons of each group. The results obtained from these experiments are being compared with the observations made of the fluorescence produced by monochromatic stimulation. It has been found, in addition, that not only iodine, but bromine, potassium, and the colored oxides of nitrogen give magnetic rotation spectra. The bright-line rotation spectrum of iodine has been photographed with the 15-foot grating, in coincidence with the absorption spectrum, and a study is in progress of the relations between the two. The color of the transmitted light is with iodine bright green, with potassium yellow, and with the nitrogen oxides blue-green. The yellow seen with potassium is due to traces of sodium, which give powerful rotation at the D lines. The spectra are all discontinuous, and their study is in progress. The fluorescence spectrum and the temperature emission spectrum of iodine have both been photographed and shown to be discontinuous.

LAMBERT'S LAW AND FLUORESCENCE.

Lambert's law states that the intensity of the radiation emitted by self-luminous surfaces of solids and liquids varies in intensity with the cosine of the angle of emission. This is an empirical law based upon the observation that the sun or a red-hot iron ball appears as a uniformly illuminated disk. It is not obeyed by non-absorbing gases, as is shown by the fact that a gas flame has a greater intrinsic intensity when viewed edgewise than when observed from the side. An accidental observation made last year that the fluorescent surface of a prism of crown glass illuminated with ultra-violet light increased enormously in intensity as it was foreshortened by turning the prism made it seem worth while to ascertain whether the radiation in this case obeyed the same law as that of the gas flame. A photometric study of the luminosity of the surface at various angles of emission has been made, with the result that it has been shown that the intrinsic intensity of a fluorescent surface viewed, so to speak, within the medium increases in proportion as the apparent width of the surface is diminished by foreshortening, or, in other words, the total amount of light given off is independent of the direction, as is the case with a surface emitting X-rays.

INTERFERENCE COLORS OF CRYSTALS OF CHLORATE OF POTASH.

Thin flakes of chlorate of potash, obtained by cooling a hot saturated solution, often show interference colors of extraordinary brilliancy and purity. These colors were studied by Stokes and Lord Rayleigh, and shown to be often nearly monochromatic—*i. e.*, the reflected light, when examined with a spectroscope, was found to consist of one or more extremely narrow bands in contrast to the broad and ill-defined bands shown in the colors of thin

films obtained in the usual way. Lord Rayleigh explained the remarkable purity of the reflected light by assuming that the reflection took place from a large number of parallel twinned planes, sensibly equidistant, a steepening of the intensity curve resulting, as in the case of the Fabry and Perot interferometer. It has appeared that Stokes's explanation of the occurrence of more than one band in the spectrum by assuming two or more sets of twinned planes was unnecessarily complicated, the simpler explanation being to assume a single set of reflecting planes and consider the colors as of different orders. To test this a study of the position of the bands in the spectrum of the reflected light has been made in the visible and ultra-violet regions, the position of the bands confirming the above hypothesis. It was usually found that the first-order color occurred in the infra-red.

Zahm, Albert F., Catholic University of America, Washington, District of Columbia. Grant No. 272. *Determination of resistance of air to moving bodies.* (For previous report see Year Book No. 4, p. 257.) $1,000.

Dr. Zahm reports that he has extended the atmospheric resistance measurements of cylinders down to wires of the smallest gage. He finds that the resistance of rods and thick wires is proportional to the diameter, but that this law does not obtain for fine wires, the resistance factor rapidly increasing as the diameter diminishes. On the other hand, the resistance varies exactly as the square of the velocity for all sizes, even to wires of the finest gage. The experiments were performed with wires that did not sing perceptibly and in a uniform air-stream that could be maintained steady at various chosen speeds.

Experiments are now under way to determine the lift and drift of arched surfaces at various angles of wind impact, the object being to investigate the shapes most useful for the sustaining surfaces of gliding and flying machines.

PSYCHOLOGY.

Farrar, Clarence B., Sheppard and Enoch Pratt Hospital, Towson, P. O., Maryland. Grant No. 350. *Experimental studies on structure and functions of the cerebral cortex, its histopathology and physiological psychology.* (For previous report see Year Book No. 4, p. 263.) $1,000.

An experimental study on the reparatory activities of the cortex cerebri was delayed in publication and is now in press (Histologische u. histopathologische Arbeiten über die Grosshirnrinde, Jena, Fischer). Porous foreign bodies were introduced into the gray cortex of rabbits under aseptic conditions and the reparatory changes observed from the sixth hour to the end of the fourth week.

The study furnishes interesting information as to the mutual relations of ectodermal, mesodermal, and hematogenous elements in the cortex cerebri, as well as concerning the genesis of blood-vessels and the fibrillar substances in their walls.

A second study, not yet published, concerns the development of the pia-arachnoid. A complete series of chick embryos was used, beginning with the earliest stage of incubation. The arachnoid is seen to be in no sense a separate membrane. The pia and arachnoid are one and represent, respectively, a highly vascularized and poorly vascularized inner and outer portion of an identical tissue. The only lymph cavities discovered are the arachnoidal spaces themselves and the intra-adventitial spaces of the blood-vessels.

On the clinico-psychologic side the wards of the Sheppard and Enoch Pratt Hospital have still been drawn upon for material. The object has been to give extended study to individuals and small groups of patients, which are then carefully analyzed and compared. In this way it is hoped to contribute a little perhaps to the possibilities of differentiation in mental diseases. In connection with the course in clinical psychiatry in the Johns Hopkins University the publication has been commenced of a series of type biographies, presenting as completely as possible the clinical course and psychologic analysis of illustrative mental cases. The first three histories have been completed: (I) Dementia präcox; (II) Depressio affectus; (III) Depressio psychomotoria, appearing, respectively, in the American Journal of Insanity for April, July, and October, 1906.

The group of devolutional psychoses has also been made the subject of special study and certain provisional subtypes differentiated. At the invitation of the British Medical Association a paper was presented on this subject at the Toronto meeting, August, 1906, and was published in the British Medical Journal (September 29) and in the Edinburgh Review of Neurology and Psychiatry.

Franz, Shepherd I., McLean Hospital, Waverley, Massachusetts. Grant No. 80. *Investigation of the functions of the cerebrum with special reference to the functions of the association areas.* (For previous report see Year Book No. 4, p. 263.) $1,000.

Abstract of Report.—The work on the frontal lobes has been completed. A short account of the results was read before the section of pathology and physiology of the American Medical Association at the meeting in Boston, June, 1906, and this paper is now in type for the journal of the association. A fuller account of the experiments conducted by Dr. Franz, with a critique of previous physiological and clinical investigations, will be published soon in an appropriate physiological or psychological journal. The results of the experiments and the conclusions to be drawn therefrom may be summed up as follows: In monkeys as well as in cats the frontal lobes are normally employed in the formation of simple sensory motor associations. When the frontal lobes are destroyed recently formed habits are lost, but it has been found possible for the animals to form new associations and to relearn old tricks. When the associations are firmly established destruction of the frontal lobes is not always followed by a loss of such habits. There are in these cases all degrees of memory for any particular habit, from "perfect" to a very decided hesitancy and slowing. In this latter event the cerebral path is probably shortened, and the nervous connection of the sensory and the motor elements of the association takes place through the connections made in the mid-brain. The association has taken on the character of a reflex. The experiments show clearly that not only are there mental changes coincident with brain lesions, but that the mental difference is one that could not be determined by simple observational methods. They suggest, furthermore, that for the determination of mental defect in man following cerebral disturbances the usual clinical observational methods are not of great value, and that more accurate physiological and psychological experiments should be made.

Work on the functions of the temporal lobes has been continued and an article on this subject is in process of preparation.

TERRESTRIAL MAGNETISM.

DEPARTMENT OF RESEARCH IN TERRESTRIAL MAGNETISM.*

By L. A. Bauer, Director.

Owing to the great amount of field work in operation, which was undertaken on account of the reasons given in the report of the previous year, the office investigations have of necessity been curtailed. The progress made during the year in the office and in the field is as follows:

OFFICE WORK.

Investigation I.—*Study of the secular variation and compilation of data preparatory to publication on a uniform plan.*—As related in the heading "Field work" a number of secular variation stations have been established. The compilation and the discussion of data have been continued as opportunity offered. For certain countries the compilations have been completed.

Investigation II.—*Discussion and publication of the data on the magnetic perturbations observed during the eruption of Mont Pelée, Martinique,* 1902.—This work is about 80 per cent completed; the final discussion had to be temporarily discontinued by reason of the more pressing duties, but it is confidently expected that the investigation can soon be brought to a close.

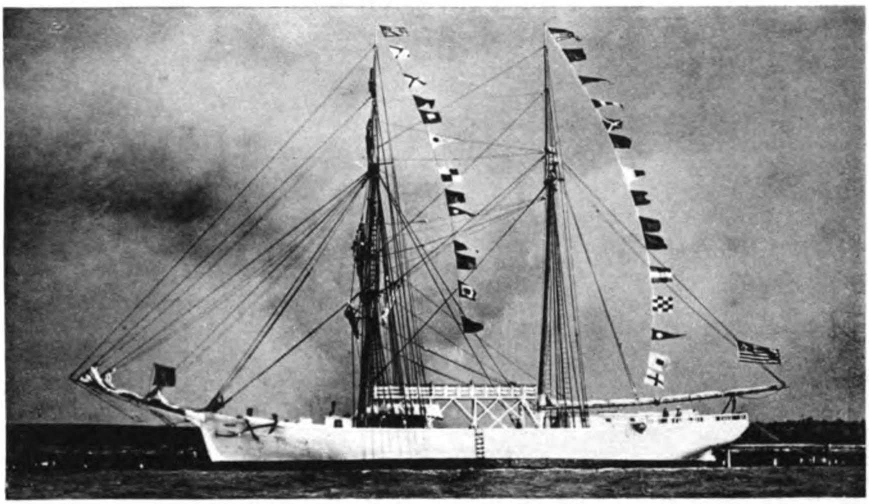
Investigation III.—*A general study of the laws of the diurnal variation to serve as a basis for determining corrections and their reliability for the reduction of field observations.*—Work along this line has been confined chiefly to the collection of data. The Department has also secured the results of the valuable series of declinations obtained by Mr. W. J. Peters while in charge of the scientific work of the Second Ziegler Polar Expedition in the Franz Josef Archipelago in 1903 and 1904.

Investigation IV.—*Special investigation of magnetic storms, with the view of determining a working method for the discussion and analysis of such fluctuations.*—These studies have been continued under the direction of Prof. Adolf Schmidt, in charge of the Potsdam Magnetic Observatory, with the aid of funds supplied, with the approval of the Executive Committee, by the Department. Owing to Professor Schmidt's multitudinous duties during the present year, it has not been possible for him to do more than make a preliminary report.

Investigation V.—*Discussion of the magnetic and electric observations made during the total solar eclipse of August 30, 1905.*—During the year considerable progress has been made in the reduction of the observations made by the Department at its stations, Battle Harbor, Labrador; Turnavik, Labrador; Black Point, Nova Scotia; Missinaibi, Canada, and Tripoli,

* Report for the year ending October 31, 1906. Grant No. 312. $56,000 for investigations and maintenance. (For previous reports see Year Book No. 3, pp. 68–74, and Year Book No. 4, pp. 264–274.)

VIEW OF "GALILEE," SHOWING SPECIAL OBSERVING BRIDGE AND INSTRUMENTS USED IN OBSERVATIONS.



THE "GALILEE" AT SAN DIEGO, CALIFORNIA, FEBRUARY 22, 1906.

Algeria. The great interest in this investigation generally among magneticians is evidenced by the fact that in addition to the stations reported as participating in the last annual report of the Department observations have now been further received from 38 stations and are in the course of reduction.

Professors Elster and Geitel and Dr. Harms have made a full report on the atmospheric electricity observations made by them under the auspices of the Department at Palma, Majorca. This report has already been printed in the journal Terrestrial Magnetism and Atmospheric Electricity, March, 1906.

The Department has also been favored by a report from Dr. H. Ebert on his atmospheric electricity observations at Palma, Majorca, which has been published in the December, 1905, number of the journal referred to above.

Two reports on the observations at Tripoli, Algeria, made by Professors Palazzo and Oddone, under the auspices of the Department, have been received and a third is in preparation.

Miscellaneous.—A card index of all observatories and institutions either engaged or interested in magnetic work has been prepared. The card catalogue of publications and investigations in terrestrial magnetism and atmospheric electricity and allied subjects has been continued, as also the collection of information as to work accomplished and proposed.

The preparation of the "Scientific report of the Ziegler Polar Expedition" for publication and the reduction of the observations, owing to the appointment of Mr. W. J. Peters, in charge of the scientific work of that expedition, to the command of the Magnetic Survey vessel *Galilee,* were undertaken under the auspices of the Department under the direction of Mr. J. A. Fleming. The expense incurred was chiefly borne by the Ziegler estate. Mr. Fleming, with the aid of temporarily employed assistants, made such good progress that the printed report is expected to appear about the end of the present year.

In connection with studies for the improvement of methods of observation and computation at sea, Mr. G. W. Littlehales, consulting hydrographer, prepared an article upon the probable error of the determination of position at sea by the methods at present used, as also such other reports as were required for the work of the *Galilee*. Various special computations and investigations of formulæ have been made as the occasion arose in the reduction of the sea observations.

From time to time during the year numerous abstracts and reviews of the current literature along the lines of the work of the Department have been prepared and published by its members. Chief among these are the reviews of articles on atmospheric electricity by Mr. J. E. Burbank appearing in the March, June, and September issues of the current volume of the journal Terrestrial Magnetism and Atmospheric Electricity. Various articles have also been prepared during the year on the work and progress of the work of the Department for different journals.

FIELD WORK.

In pursuance of the plan already announced of a general magnetic survey of the accessible regions of the globe within a period of fifteen to twenty years and of the general investigation of the secular variation, the following observational work has been executed or is in progress:

A.—Magnetic Survey of the Pacific Ocean.

The employment of the yacht *Galilee* has been continued during the year. At the end of the last fiscal year she had just left Honolulu for Fanning Island, where the party arrived October 10, 1905. After the necessary harbor swings and shore observations a course was taken south to about 1.5° south latitude in longitude 162.8° west, which point was reached on October 17, whence a northward course to meridian 169.5° to the west-northwest of Honolulu was pursued, the expedition arriving again at Honolulu on November 7. Leaving November 12, a northwesterly course was followed to about 28.2° north latitude and longitude 163.5° west, from which point the expedition proceeded somewhat north of latitude 41.2° in longitude 150.3° west and thence followed a direct course to San Diego. The first cruise was thus completed at San Diego on December 9, 1905, a distance of about 11,000 nautical miles having been covered. The necessary swings and shore observations were made between December 11 and 18.

Upon the completion of these observations the work of alterations on the ship and instruments as indicated by the experience of the first cruise was taken in hand. In order to settle the various matters pertaining to the continuation of the work and the proposed alterations the director found it necessary to make a trip to the Pacific coast. Owing to the obligation of the members of the scientific personnel, with the exception of Mr. J. P. Ault, who was in the permanent employ of the Department, to return to their duties with the United States Coast and Geodetic Survey at the expiration of their furloughs, it was necessary to reorganize the staff. Mr. W. J. Peters, who has had charge of scientific exploring parties of the U. S. Geological Survey in Alaska and had been second in command and in charge of the scientific work of the Ziegler Polar Expedition, was appointed the new commander. To him were assigned as assistants Mr. J. P. Ault, Mr. J. C. Pearson (formerly instructor in physics at Bowdoin College, Maine), and Dr. H. E. Martyn, surgeon and recorder. Mr. Peters took command of the party in January, 1906. The alterations were made chiefly under the direction of Mr. J. F. Pratt, the former commander, who also rendered Mr. Peters the required assistance in taking command. The alterations, harbor swings and shore observations having been completed preparatory to the inauguration of the second cruise, the *Galilee* left San Diego on March 2 last and took a direct course for Fanning Island. A stay of ten days from

March 31 to April 10 was made at this port, during which time all necessary check shore and swing observations were made at the stations occupied on the first cruise. The next stop was made at Pago Pago, Samoan Islands, from April 26 to May 1. On account of severe local attraction, as also because of lack of tug facilities, no harbor swings or shore observations were made at this point. At Apia, Samoan Islands, May 2 to 10, comparisons were made between the *Galilee* instruments and those of the German Observatory in charge of Dr. Franz Linke, to whose kindness and extension of all possible courtesies the Department is indebted. Harbor swings were not made owing to the lack of sufficient tug facilities and to the strong harbor currents. At the next port, Suva, Fiji Islands, comparisons were made between the instruments of the ship and those used by Mr. G. Heimbrod, magnetic observer in charge of the work on the islands of the South Pacific. Harbor swings were also secured at this point during the stay there between May 17 and 26. Jaluit, of the Marshall Islands, was reached on June 21 and shore and harbor sea observations were made, after which a course was taken for Guam Island on June 30. During July 11 to 24, harbor swings and shore observations were made at San Luis d'Apra, Guam Island. Thence sail was set for Yokohama, Japan, where the expedition arrived on August 13 last. At this port numerous shore observations as well as harbor swings were made, as also, through the courtesy of Dr. K. Nakamura, in charge of the Central Meteorological Observatory of Tokyo, and of Dr. A. Tanakadate, of the University of Tokyo, comparisons with the observatory standards of Japan were secured. On August 24 the *Galilee* was blown on the breakwater at Yokohama by a typhoon and such damage sustained that she had to be dry-docked in order to have the necessary repairs made. Fortunately the damage was not very serious and she was enabled to take up her work again on September 6, on which date the expedition left Yokohama for San Diego. At the end of the fiscal year the vessel was thus en route to San Diego, upon the arrival at which port, on October 20, she had terminated the second cruise of the Magnetic Survey of the Pacific Ocean and had covered on this cruise approximately 15,000 nautical miles, or a total of 26,000 nautical miles for the two cruises.

Throughout, observations have been made of the three magnetic elements as frequently as the weather and sea conditions would permit. The preliminary reductions indicate that the sea work has attained a high state of efficiency, and that a most satisfactory degree of accuracy has been reached. An article on the instruments, methods, and preliminary results of this work has been published by the director in the June number of the current volume of Terrestrial Magnetism and Atmospheric Electricity, this article being the summary of two addresses delivered before the Philosophical Society of Washington and before the American Physical Society. As soon as the

second cruise has been completed and all of the control observations have been made, the final reduction and publication of the work of the two cruises will be undertaken.

The need of the ocean magnetic survey, viewed from a practical as well as a scientific standpoint, is most emphatically shown by the comparison of the charted and observed values of the magnetic elements contained in the article referred to above. Thus, the present isogonic charts of the Pacific Ocean show values too small between San Francisco and Honolulu by amounts ranging from 1° to 2°; the isoclinic charts, values too low by about 1°, while the charts of lines of equal horizontal intensity give uniformly too high values on the average of one twenty-fifth part.

While the deviation coefficients of the *Galilee* have been found to be smaller than those of any vessel thus far engaged in oceanic magnetic work, the need of a specially constructed, non-magnetic, auxiliary-powered sailing vessel has become more and more patent as the work has progressed. With such a vessel the cost of maintenance and operation would be reduced and results of the desired accuracy be obtained with much less labor than is possible when consideration must be paid to the determination of deviation corrections.

B.—Land Work.

China.—Dr. C. K. Edmunds, the magnetic observer in charge of the work in China, has executed during the past year valuable series of observations. Through the courtesy of Dr. W. S. Doberck, the director of the Hongkong Observatory, and that of the governor of Hongkong, he secured the loan of a Kew dip circle and magnetometer with tripods and theodolite, which, with remainder of outfit supplied him by the Department, enabled him during January and February to carry out a magnetic survey of Hainan Island. Standardization observations were made at Kowloon (Hongkong Observatory) both before and after the trip. Eight stations were occupied on the island of Hainan and vicinity as follows: Hoihow, Cape Kami (Lei Chan Peninsula, Kwangtung Province), Hiongpo, Yaichau, Yulinkan, Leong Sui, Kacheck, and Honglok (near Canton, Kwangtung Province). The region thus covered was, magnetically speaking, unexplored. Dr. Edmunds reports that several of his stations have never before been visited by a Caucasian. On the completion of this campaign Dr. Edmunds returned to his duties at the Canton Christian College.

In May Dr. Edmunds, through the courtesy of Father J. de Moidrey, director of the Zi-ka-wei Observatory, secured the loan of the small French instruments belonging to the observatory. During the latter part of May he made the necessary comparisons at the Hongkong Observatory between the Kew instruments used in the Hainan work and the French instruments.

With the latter outfit he again took up field work in June, this time along the coast from Swatow northward. Up to August 12 he had occupied the following stations: Honglok, Swatow, Chau-chu-fu, Amoy, T'suan Chau, Fuchau, An Tau, Yangchau, Chinkiang, Suchau, and Shanghai (Zi-ka-wei Observatory). In the execution of this work he was very materially assisted by the American vice-consul at Fuchau, the Hon. E. Carleton Baker, to whose aid and advice much of the success of the trip is due.

Dr. Edmunds during the time remaining at his disposal for field work has been able to occupy, through the extension of the privilege of passage on the revenue cutters by courtesy of the inspector of general customs, Sir Robert Hart, and the coast inspector, Captain T. J. Eldridge, eleven stations distributed in the neighborhood of the lights in the Chusan Archipelago and in the neighborhood of Cheefoo, Tientsin, and Naichwang. In securing this valuable aid he has been ably assisted by the American minister at Peking.

South Pacific Islands.—Mr. G. Heimbrod, magnetic observer, continued at the German Magnetic Observatory under the direction of Dr. Franz Linke, at Apia, Samoan Islands, until March 17. Up to this time he was engaged in the determination of the various methods of observation and constants of the magnetometer and dip circle, courteously loaned to the Department by the observatory. He also familiarized himself with observatory work.

Since leaving Apia, Mr. Heimbrod has made magnetic observations at the following stations: Suva, Viti Levu, Fiji Islands (three stations); Rotumah Island; Tilingitha Island; Suva, Viti Levu, Fiji Islands (comparisons of his instrumental outfit with that of the *Galilee* and determinations of corrections and constants of dip circle No. 171 supplied him from the *Galilee* to replace the one loaned from the Apia Observatory); Nukulau Island; Niakombi Point, Levuku Ovalau, Fiji Islands; Vagadace, Levuku Ovalau, Fiji Islands; Christchurch, New Zealand; several stations in the Society Islands, including Tahiti Island, also in the Paumotu, or Low Archipelago, and Rarotonga Island of the Cook Group. At the end of the fiscal year Mr. Heimbrod was en route to Auckland, New Zealand, and Sydney, Australia.

The observations at Christchurch will furnish a direct correlation between the standards used by the Potsdam, Cheltenham, Apia, and Christchurch magnetic observatories, as also between the instruments used by the British Antarctic and the German Antarctic expeditions and by the *Galilee* in the Magnetic Survey of the Pacific Ocean.

From several of Mr Heimbrod's stations important contributions to the secular variation data have been obtained.

Canada.—In order to furnish data for the completion of the magnetic survey of the region of the earth bounded by the parallels of latitude 20° and 49° north and the meridians of 65° and 125° west, the director, together

with Mr. P. H. Dike, magnetic observer, and Mr. E. H. Bowen, computer, determined the three magnetic elements during September and October at about 70 stations, nearly uniformly distributed over southern Canada between the meridians 70° and 105° west longitude. This region is the one covered by Lefroy in his magnetic survey of 1842 to 1844, and several of his stations were reoccupied, and thus important secular variation data were obtained. These observations will at the same time complete the magnetic survey of a very large quadrilateral of the earth's surface when taken in connection with the magnetic work of the United States Coast and Geodetic Survey; the work will, moreover, all be based upon one standard. From so large an area valuable contributions to the theory of the earth's magnetism will doubtless result. In connection with the work in Canada a comparison of the standard instruments of the Toronto and of the Cheltenham observatories was also secured.

The various necessary testing observations and standardizations of instruments have been made at Washington and at the Cheltenham Magnetic Observatory during the year, mainly by my chief assistant, Mr. J. A. Fleming, and Magnetic Observer D. C. Sowers.

C.—Magnetic Disturbances.

The two direct recording declinometers after the design and construction of Dr. W. G. Cady, research magnetician, have been completed. As already reported, one of these instruments has been supplied to the Solar Observatory of the Carnegie Institution of Washington, where it has been in operation since March. The second instrument has been temporarily installed at the office of the Department. An article by Dr. Cady on this instrument will be found in the September, 1906, issue of the journal Terrestrial Magnetism and Atmospheric Electricity.

D.—Atmospheric Electricity.

Mr. P. H. Dike, magnetic observer, made an investigation at the Cavendish Laboratory, under the direction of Prof. J. J. Thomson, on the diurnal variation of the amount of radioactive emanation in the atmosphere. An account of this work has been published in the September number of the current volume of the journal Terrestrial Magnetism and Atmospheric Electricity.

Mr. J. E. Burbank, magnetician, has completed a report on his atmospheric electricity observations made at Battle Harbor, Labrador. He has also made some observations of the atmospheric radioactivity at Washington, showing the presence of thorium in the air. An account of this work appeared in the June, 1906, issue of the journal Terrestrial Magnetism and Atmospheric Electricity. Mr. Burbank also made some preliminary tests of instruments to be used in atmospheric electricity work at sea.

ZOOLOGY.

Castle, W. E., and **Mark, E. L.,** Harvard University, Cambridge, Massachusetts. Grant No. 331. *Experimental studies in heredity.* (For previous reports see Year Book No. 3, p. 136, and Year Book No. 4, p. 276.) $500.

Drs. Castle and Mark are associates of the Department of Experimental Evolution at Cold Spring Harbor, and their work has been done in cooperation with that of the Department.

Abstracts of Reports.—Dr. Castle reports that observations have been made upon about 2,000 guinea-pigs, 1,000 rabbits, and 1,500 rats reared from pedigreed stock. The general questions concerned are, (1) what sorts of variations are concerned in the processes of evolution, and (2) what are the laws governing their transmission? As in previous years, much attention has been given to color-inheritance, being concerned this year chiefly with color-patterns, particularly with their modification by selection. Other characters studied are polydactylism, skeletal dimensions, general size, and ear-characters. The contrasted "mutation" and "selection" theories as to the origin of new organic forms have been kept constantly in mind, and it is concluded that both are important in evolution. Latent inheritance and reversion have received considerable attention, and a most interesting experiment has been an attempt to fix a reversionary heterozygous character, the agouti coat of guinea-pigs, identical in its general features with the coat-color of wild cavies.

The results of some selection experiments extending over several years are ready for publication, and others are in preparation. Anatomical studies have been made of hybrids between the guinea-pig and *Cavia aperea* of Brazil. The hybrids are of remarkable size and vigor, but completely sterile. A second importation of *Cavia aperea* from a different part of Brazil was unfortunately lost in the long ocean voyage to this country.

Student assistants in the work and the topics upon which they have been engaged are indicated in the following list:

(1) Mr. P. C. Ackerman. The anatomy of the four-toed foot in the polydactylous race of guinea-pigs; is it atavistic or not? Probably atavistic.

(2) Mr. H. R. Fulton. Can giant and dwarf races of guinea-pigs be established by selection; if so, are they stable races? This investigation is still in progress.

(3) H. MacCurdy. Can color-patterns among spotted guinea-pigs and rats be fixed by selection? They can not; but selection can fix within certain limits as racial characters particular amounts of pigmentation; that is, spotted races can be created at will which bear either much pigment and little white fur or the reverse, much white and little pigment. One can not at will fix the *position* of the pigmentation, either on the anterior or on the posterior part of the body, or in any other arbitrarily selected position. This investigation is completed and ready for publication.

(4) R. C. Mullenix. The inheritance of skeletal dimensions among rabbits.

(5) J. T. Nichols. The inheritance of skeletal dimensions among guinea-pigs. The results of these two related investigations have not yet been fully analyzed, but the inheritance is apparently fully blending.
(6) A. S. Pearse. The inheritance of polydactylism in guinea-pigs. A continuation of the investigation described in Publication No. 49 of the Carnegie Institution of Washington.
(7) W. G. Vinal. Certain problems in color inheritance among guinea-pigs. In progress.
(8) H. E. Walter. Ear-length and color-inheritance among rabbits. This first part is finished and nearly ready for publication, the second part in progress.
(9) A. Gulick. Skeletal characters of the sterile hybrids between the guinea-pigs and *Cavia aperea*.

Dr. Mark reports that a good beginning has been made on the study of the sexual cells of hybrid fowls, and satisfactory methods of fixation and staining have been worked out. As rapidly as the material can be spared from the station at Cold Spring Harbor, where it is being bred for this and other experiments, it is being prepared by Miss Lutz for microscopic study.

A study of the histological conditions of the male sex-cells in domesticated guinea-pigs (*Cavia cobaya*) and in hybrids resulting from crosses of these with the wild guinea-pig (*C. aperea*) has also been carried on. Several thousand sections have been prepared, and it has been possible to make out from these marked differences between the domesticated and the hybrid individuals, which it is hoped may lead to valuable results.

It has also been possible to reach some interesting results in the study of the formation of spermatozoa in honey bees, and a preliminary paper covering some of the points established has already been published by us. These studies will be extended to embrace other Hymenoptera, material for which has been secured during the past summer.

Crampton, Henry E., Columbia University, New York, N.Y. Grant No. 137. *Determination of the laws of variation and inheritance of certain Lepidoptera.* (For previous reports see Year Book No. 2, p. XLI, Year Book No. 3, p. 136, and Year Book No. 4, p. 276.) $500.

Report.—In continuing the work of former years additional pedigreed families of *Philosamia cynthia* have been reared, and statistics relating to elimination, sexual and other forms of selection, correlation, and inheritance have been obtained for more than 2,000 additional individuals. Of the four series of pupæ produced during the previous year (as described in previous reports) more than 4,000 became moths in June and July, 1906, and these were mated in 425 cases. Three hundred and nine of these pairs gave 44,418 eggs. Only 69 families, however, were reared, and these gave 2,196 cocoons in August. As in previous years, it was found that some individuals emerged during the latter part of the summer when they were reared, although there were less than 200 such cases this year. The moths that emerged were mated in nearly 50 instances and 5,845 eggs were obtained from these pairs. Some of these are now being reared.

With the emergence of the pupæ now on hand during the early summer of 1907 the acquisition of statistics in connection with the present research will be regarded as concluded. Ten thousand and more pedigreed individuals produced since 1903 will afford ample material for the statistical treatment of the problems of variation, selection, correlation, and inheritance. The data will gain an additional value because of the opportunity for comparison with figures obtained during the years 1899–1903, relating to many thousands of "wild" individuals.

Duerden, James E., Rhodes University College, Grahamstown, So. Africa. Grant No. 288. *Continuation of investigations on the morphology and development of recent and fossil corals and physiology of the Zoantharia.* (For previous reports see Year Book No. 2, p. XLI; Year Book No. 3, p. 137, and Year Book No. 4, p. 277.) $750.

Abstract of Report.—(*a*) *Morphology and development of recent corals.*—Work has been continued upon the Pacific corals collected in the Hawaiian Islands during 1904, and the seventh of the series of papers dealing with the morphology of the Madreporia has been published. The contribution "Intrapolypal tentacles" describes a peculiar modification undergone by certain of the tentacles in species of Pocillopora. Studies on variation by statistical methods have been continued and are yielding results of much interest.

(*b*) *Fossil corals.*—During the year an attempt has been made elsewhere to controvert the hexamerism of the Rugose corals, a condition claimed by the author as a result of previous investigations. From further studies upon fossil specimens it has been possible to demonstrate a primary hexameral condition for several additional species of Rugose corals, so that no doubt can now be entertained as to the correctness of the original conclusions. Two papers, containing further evidence upon the subject of the primary septa of fossil corals, are now in press.

(*c*) *Physiology of the Zoantharia.*—A paper, "The rôle of mucus in corals," has been published and contains an account of the important part which mucus plays in the feeding of living polyps. Another contribution, "On the habits and reactions of crabs bearing Actinians in their claws," has also been published and discusses the various relationships involved in this peculiar form of commensalism.

Howard, L. O., U. S. Department of Agriculture, Washington, D. C. Grant No. 250. *Preparation of an elaborate monograph on American mosquitoes.* (For previous reports see Year Book No. 2, p. XLII; Year Book No. 3, p. 138, and Year Book No. 5, p. 279.) $3,000.

Abstract of Report.—Dr. Dyar has made some collections in southern California, and has done some breeding in that part of the country, and additional material has been coming in from Trinidad, British West Indies, and from Florida. Additional observations have been made by volunteer assist-

ants, and some new data have been gained in this way. The recipient of the former grants has been engaged, with the assistance of Dr. H. G. Dyar and Mr. Frederick Knab, in systematic work upon the material brought together by the operation of the grants. Very many new illustrations have been made, and it is hoped to complete the monograph early in 1907.

Mark, E. L., Harvard University, Cambridge, Massachusetts. Grant No. 346. *Significance of the fact that in mice two forms of eggs are produced, and its bearing, if any, on heredity.* $300.

Report.—Dr. Mark and Mr. J. A. Long are conducting these investigations in cooperation with the director of the Department of Experimental Evolution. They report that work is advancing satisfactorily and a considerable number of microscopic slides of great value have been prepared. A part only of these have been studied in detail, but careful drawings of some of the more important sections have been made.

Morse, Albert P., Wellesley, Massachusetts. Grant No. 284. *Research on North American Acridiidæ, with especial reference to biology, distribution, and variation.* (For previous report see Year Book No. 4, p. 283.) $1,000.

Abstract of Report.—During the latter part of the trip of reconnoissance of the States of the lower Mississippi Valley, made in the summer of 1905 for the purpose of securing data on the biology and distribution of the locust fauna of that section of the country, observation was directed particularly to the transition area between the humid and arid sections, and to the status of brachypterous species in the treeless districts visited. Based upon the data secured upon this trip, it would appear that as a whole the biota of the treeless plains and prairies is characterized by an Acridian fauna richer in number of species than that of the East, and that these are of geophilous and campestrian character, in consonance with the climate and the habitats represented. While differing much in general facies from that of the Eastern States of the same latitude in these particulars, the transition is gradual rather than abrupt (agreeing with the physical conditions), the border-land being peopled with numerous genera and species of very wide distribution, sometimes transcontinental, sometimes restricted to the district between the Mississippi River and the Rocky Mountains, but occurring both in the humid and arid sections of this region.

Brachypterous species are much less numerous proportionally in treeless arid districts than in humid forested regions, East or West. When present they inhabit shrubby or herbaceous thickets. It is a noteworthy fact that (excluding the aberrant group Tettiginæ) every flightless species of locust known from the eastern half of the continent is phytophilous, as contrasted with geophilous, in habits.

Several local lists of the species secured, characteristic at that season of the year of the different portions of the region traversed, together with notes on their habits, have been prepared for convenience of reference. These are accompanied by a series of photographs illustrating some of the typical habitats in which they live.

The body of the report consists of a complete annotated systematic list of the species taken, with full data and descriptions of several forms new to science.

Naples Zoological Station, Naples, Italy. Grant No. 332. *For maintenance of two tables.* (For previous reports see Year Book No. 2, p. CLIV, Year Book No. 3, p. 145, and Year Book No. 4, p. 288.) $1,000.

As in previous years, the grant was made to aid the laboratory in paying for the maintenance of two research-tables. The director of the laboratory assigned the tables during the past year to Dr. Naohidé Yatsu and Dr. Raymond Pearl. Abstracts of reports by these investigators will be found in the following pages.

Pearl, Raymond, University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 345. *Completion of investigations by statistical methods on variation and correlation.* (For previous reports see Year Book No. 3, p. 140, and Year Book No. 4, p. 285.) $500.

Abstract of Report.—The year was spent in work at the following European laboratories: Zoologisches Institut, at Leipzig; Biometric Laboratory, University College, London; and the Stazione Zoologica, at Naples.

The following investigations were completed, and the papers detailing the results will appear shortly:

(1) A biometrical study of conjugation in Paramecium. The results of this work may be summarized as follows:

(*a*) It was demonstrated that the conjugant individuals of a Paramecium population are distinctly differentiated in size and shape of body, both in respect to type and variability, from the non-conjugant portion of the population living in the same culture at the same time.

(*b*) There is a high degree of homogamy in the pairing of individual Paramecia in conjugation. Individuals like one another in size and shape of body tend to conjugate together.

(*c*) It was shown that this homogamy can not be accounted for either by any form of random pairing or by a process of equalization in size after conjugation has occurred.

(*d*) A definite physiological basis for the homogamy is assigned, and it is shown that the existence of homogamy in conjugation and the differentiation of conjugants from non-conjugants have significant theoretical bearings in the interpretation of the life history of Paramecium.

The complete paper on this work will appear soon in Biometrika.

(2) A study of variation in relation to differentiation and growth in Ceratophyllum. It is impossible in an abstract to give an adequate summary of the results of this study. Some of the more important of the general results are the following:

(*a*) A thorough analysis of the facts of variation in the plant as a whole and in its constituent axial elements was made. From this analysis it was possible to work out the *biological* factors concerned in the genesis of characteristic frequency curves of variation more completely than has hitherto been done for any organism.

(*b*) The analysis led to the establishment of two laws of growth, which serve to describe very exactly and completely the observed phenomena of variation and differentiation in leaf whorls, branch production, etc., in the plant.

(*c*) The first of these laws has been designated the "logarithmic law of growth." For Ceratophyllum it states that the size of parts on any axial division of the plant increases as we pass toward the distal end of that division, but the *rate* of this increase steadily diminishes the farther distad we go. As a general law of growth, this may be stated as follows: The increase by growth of a part or character is quantitatively expressed by an equation of the form

$$y = A + C \log (x - a)$$

or some closely related logarithmic equation. In this equation y denotes size of the growing part or character, x stands for the time factor, and A, C, and a are constants.

(*d*) The second of these laws is that in accord with which the variability of an organism or its parts steadily diminishes with growth.

The complete paper on this work will appear shortly as Publication No. 58 of the Carnegie Institution of Washington.

(3) A study of the relation of variation and correlation to morphological differentiation and homology in the appendages of the crayfish. This work led to the general result that physiological and ontogenetic factors are relatively much more important in influencing the degree of variation or correlation of parts than are morphological and phylogenetic factors. Lack of space forbids a general summary of the results of the paper, which is now in press, and, it is hoped, will appear shortly.

(4) Experimental studies on variation and correlation in Protozoa. The work on Paramecia of known ancestry reared under controlled environmental conditions has been practically completed, but the results are withheld from detailed publication until further experiments along similar lines have been made. A preliminary paper dealing with a portion of the results has appeared during the year. In this paper it is shown that while under normal circumstances rigid selection of ancestry markedly reduces the variability of

Paramecium, yet by proper environmental conditions it is possible to obtain a population which, in spite of its selected ancestry, shows just as great variability as does a "wild" population of unselected ancestry. A paper dealing with variation and correlation in Chilomonas has been completed and is now in press.

(5) The material on variation in the whitefish (Coregonus), to which reference has been made in previous reports, has been reduced, and a paper giving an account of the results will be ready for the press soon.

(6) Several minor papers dealing with specific problems of variation and correlation have been completed during the year, and have either appeared or are now in the press.

In continuation of the investigation of the problems of variation and correlation, it is proposed to carry forward the work along two principal lines, viz, (*a*) work on Protozoa, and (*b*) analysis of the laws of growth.

Tower, William L., University of Chicago, Chicago, Illinois. Grants Nos. 181 and 251. *Experimental investigations of the production and preservation of new character races and species in insects.* (For previous reports see Year Book No. 3, p. 141, and Year Book No. 4, pp. 286–288.) $1,945.

Abstract of Report.—The studies with Leptinotarsa since 1904 have been along four chief lines:

1. Pedigree breeding and the experimental production of new races.
2. Transplantation experiments in nature in southern Mexico.
3. An experimental statistical investigation of natural selection.
4. The ecology of the material under investigation.

While investigations under these grants have been largely concerned with the genus Leptinotarsa, it seemed desirable to extend them to the related genera of the essentially American group. This was begun in the year 1905 and has been continued during the past year. The work upon these other forms has been largely preparatory, consisting in a compilation of all known data concerning their distribution, variation, habits, etc. Preliminary pedigree cultures of different species of Calligrapha, Zygogramma, Stilodes, Labidomera, Doryphora, and Melasoma are being made, and this material will later form the source of supply for experimental studies.

General results derived from these investigations.—In these investigations, which have now been in progress for more than twelve years, an attempt has been made to view animal evolution in a restricted group from as many viewpoints as possible and thus to be able to correlate and check the results obtained from different minor parts of the main problem.

The investigation of the phenomena of variation in its diverse aspects has given the general result that, as far as this material is concerned, there is no indication of indeterminate variability—that is, all variations thus far studied are in few directions, and in the case of any particular species are determinate irrespective of their size or behavior in inheritance. Variations,

as far as it is possible at the present time to decide, are never predetermined, but are always the direct result of the response of the developing organism to stimuli, and these stimuli seem to be primarily external. Although it is becoming clearer with each year's work that variations are responses to stimuli, as yet there are no indications that the variations are trophic in their nature, but that different stimuli produce the same results.

A point of importance is the continuity of variations found, there being no indications that there exists in any sense the isolation of variations or "unit characters" as postulated by De Vries. Variations may form with rapidity, but there are always to be distinguished intermediate steps which grade into one another.

The data and conclusions concerning heredity derived from these investigations, while of interest and suggestive, may easily be overestimated in their value. In Chrysomelid beetles not all inheritance is Mendelian in character; but as far as determined only characters that are "general characters" in the organism are thus inherited. The minor characters differ in different species and also according to the character, no general rule being followed as far as it has been possible to discover. It is hoped that the pedigree cultures now going can be continued without accident for a term of years, thus giving data upon the questions of heredity from known pedigreed families.

Whether species have developed by accumulated variations and natural selection or by mutation and natural selection is perhaps the question of greatest interest at this time. The results derived from the study of variation and the data of the transplantation experiments, when added to the information gained in nature of this problem, shows that in these beetles the method of evolution is an orthogenetic, rapid transmutation in response to stimuli, according to the method of trial and error, with natural selection and segregation acting as the factors to conserve the developing race. All evidence points to the general conclusion that species have arisen through the progressive and continuous modal shifting of the evolving, segregated group, the mode representing the optimum or most stable condition existing between the organism and its environment. "Mutations"—that is, large or extreme variations—do not seem to play any part in the process as carried on in nature, but are exterminated, in the instances observed, as soon as they arise.

Wilson, Edmund B., Columbia University, New York, N. Y. Grant No. 370.
Researches in the chromosomes of insects and other animals with reference to the cytological basis of sex-production and Mendelian inheritance. $500.

Professor Wilson made an extensive field trip during the summer, south as far as Georgia and then westward across the continent in the southern region. A very large amount of material was secured, which will require a long time to work up in full.

Yatsu, N., Columbia University, New York, N. Y. Grant No. 268. *Experimental study of the Nemertine egg*. (For previous reports see Year Book No. 3, p. 144, and Year Book No. 4, p. 288.) $1,000.

Abstract of Report.—Under this grant Dr. Yatsu has continued at the Naples Zoological Station (January to June, 1906) the investigation which was begun in the summer of 1905. While at Naples most of his time was devoted to the analytic experiments on the egg of Beroë. These led to several interesting conclusions, among which may be mentioned the following: In the egg of Beroë the ctenoplasm is not definitely localized before fertilization, nor, perhaps, immediately after. At the 8-cell stage the ctenoplasm is not equally distributed in all the cells, the corner cells containing usually a larger quantity. The third cleavage of the egg of Beroë is, therefore, qualitative, as in the egg of most forms. Incidentally he studied also the mechanism of cell-division in the egg of Beroë. He cut the egg during the first cleavage at different periods and along different planes, and he studied the behavior of the "cleavage-head." This is the first instance in which cutting experiments were employed for this purpose, and he believes that his results offer at least a clue to the final solution of the problem of the mechanism of cell-division. He also studied the early cleavage stages of both the trifoil and ring embryos of *Cerebratulus marginatus* to determine the seat of the cleavage factors. His results will be published in a series of papers during the coming academic year.

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